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THE VIRTUES OF BAR AUTOMATICS
(Up to one inch capacity).

Paper presented to the Institution, Coventry Section,
by T. Brooks, A.M.I.P.E.

THE Bar Automatic is a machine tool which has become in its various forms so much a part of modern production engineering that it needs no introduction here. The purpose of this paper, therefore, is to offer suggestions for the use of this class of machine tool, rather than to discuss its construction. The limitation of capacity mentioned in the title is made, not because there is any essential difference in automatics with capacities above and below any particular figure, but because it is felt that as the size and weight of the machine increases, many of the pitfalls connected with its use disappear, on account of greater tooling space, increased section of tools, reduction of speed, etc. The figure of 1 in. has, therefore, been selected as a suitable size at which to draw a line of demarcation.

Bar automatics roughly divide themselves into three types, and as each possesses virtues peculiar to its construction they are classified for the purpose of this paper under the following headings :

Type 1.—Single spindle machines with movable head stocks and fixed tools (the Swiss type).

Type 2.—Single spindle machines with stationary head stocks and movable tools (turret type).

Type 3.—Multi-spindle machines.

The Swiss Type.

The Swiss type of automatic employs the bush turning method, in which the bar of stock is fed forward by a moving head stock against a stationary tool, being supported during the process by a bearing bush in which it is a running fit.

The advantages gained by this method are, of course, the application of support close to the cutting tool, with the result that this machine is very suitable for turning pieces of small diameter in comparison to length. Further, owing to the fact that the stock is continually supported ahead of the cutting tool, it is a simple matter to vary the diameter turned continuously or intermittently by moving the cutting tool towards or away from the centre of the bar.

This feature may be employed to cut off pieces which require to be pointed at each end, such as spindles for use in clockwork mechanism. Parts can, therefore, be made on this type of machine which cannot be produced on machines of types 2 and 3.

Another advantage of this type of machine is that its length capacity has been developed to a considerable degree, so that by comparison with the turret type of single spindle machine of equal stock diameter rating, its length capacity is roughly double, and this without any appreciable difference in floor space, size for size.

In order to take advantage of these special features, however, it is essential to feed the machine with stock of outside diameter equal in accuracy to the tolerance specified on the finished article, it being obvious that any variation or distortion of diameter of stock will be immediately transferred to the diameter of the part produced. Wear of the supporting bush is also a factor to be reckoned with, but both these difficulties have been met to a certain extent on modern machines of this type by the provision of supporting bushes which rotate in their own bearings and are positively driven by the headstock and are adjustable within limits for size in a manner similar to a collet chuck. Incidentally, these adjustable revolving bushes have opened up new fields for the machine since they may, like collets, be made to accommodate stock of unsymmetrical section. Also, the advent of very hard material has made possible the provision of steady bushes which are almost immune from wear.

The Swiss type of machine is built primarily as a simple turning machine, and that portion of the machine for dealing with operations other than turning is built in the form of an attachment. This attachment may be very simple, that is, one stationary spindle to accommodate a drill; or quite elaborate with several spindles either stationary or revolving, allowing the use of dies, taps, and small drills. The attachment is operated by a cam which is independent of those used for the bar feed and turning tool movements, and this feature is of considerable importance in dealing with certain classes of work.

For example, it is necessary to make a bolt having great length in relation to its diameter—say, $\frac{1}{4}$ in. B.S.F. by 5 in. long under the head. From the point of view of turning, this bolt can be produced on a multi-spindle machine with greater rapidity than on the Swiss type, owing to the fact that a heavier turning cut can be taken by much more powerful multi, and also the length of the cut can be divided between at least two tools. However, the multi-spindle machine, being of the fixed head type, must feed nearly 6 in. of stock out from the collet before operations commence. After the necessary length of turning has been performed, the extreme end of the piece, which is to receive the thread, is unavoidably running out of truth to a greater or lesser extent depending on the

nature of the material and the skill of the setter. There is always, then, the difficulty of persuading the die to cut a thread which is axially parallel with the shank on which it is cut, and while this error may not assume serious proportions commercially, it is looked upon with very grave concern by inspectors, for example on aircraft work.

In the Swiss type of machine this same bolt would be produced with one turning tool, but as the die is able to operate entirely independently, the thread can be produced practically simultaneously with the turning. The die (working on the overtaking principle) is allowed to commence operations when perhaps only $\frac{1}{4}$ in. of shank has been turned, and by controlling the rate of overtake it can be made to follow up the turning close behind the support bush where there is no possibility of whip in the shank. When the necessary length of thread is produced, the die is backed off and turning continues, and if at the end of the turning operation the shank shows whip, it is of no consequence because the thread is already cut. Thus the Swiss machine, while quite unable to compete in terms of pieces per hour calculated on cam time, can quite often compete very successfully in terms of good parts delivered at the end of a daily run.

Mention must also be made of a small detail which again is commercially perhaps of no importance, but which is also looked on with disfavour in aircraft work. This small detail is the "return mark." When a long piece is turned in a fixed head automatic, the necessary support is given to the piece by means of rollers working *behind* the tool. When properly set, these rollers can be made to impart a very high finish to the piece, but it is not easy to ensure that as the tool returns to the commencing position, either the tool or the rollers will not cause a spiral mark or groove on the turned diameter. Much time may be lost in overcoming this difficulty which increases rapidly with the weight of cut, thereby rendering useless to some extent the full power of the machine. All this trouble is overcome on the Swiss type of machine, since the tool does not return along the diameter it has cut. Swiss type machines are, in general, built to run up to very high spindle speeds, so that parts can be made at quite fast rates of production without forcing the tools. This is naturally conducive to high quality of finish, and the general cleanliness of product from this type of machine is, of course, fully recognised.

A further important facility offered by the Swiss type of automatic is one arising from certain features incorporated in the design of the machine. The cams which control the length of cut by moving the headstock, transmit this motion through levers having adjustable ratios, and the speed at which these cams revolve is easily changed by means of a multi-step pulley in the drive. Thus, a cam which is

designed to move the headstock through 1½ in. at an economical rate of feed cam, by reducing the leverage mentioned, and increasing the speed of revolution of the cam, be made to move the headstock through 1 in. without any sacrifice in efficiency. In other words, if a piece 1½ in. long is turned in one and a half minutes, a similar piece 1 in. long can be turned in one minute without new cams being necessary. This makes the machine particularly useful in the field of short runs, always a serious factor in a large screw machine organisation. Indeed, in many shops where the class of work is considered to be economically suitable to the Swiss type of automatic, a few of these machines are kept available for short runs, advantage being taken of the adjustable features applied to a range of more or less standard cams.

As the Swiss type of automatic is, by comparison, quite reasonably priced, this feature is very well worth investigation by engineers who are concerned with small quantity production from capstan shops, since it offers a solution of the problem of quantities which, while being rather large for capstan production, do not warrant the expense of tooling on the turret type of automatic. Further, as the tools used are nearly always, in these circumstances, of a very simple nature, it becomes possible, with the help of the suppliers, to run a certain number of these machines without employing any special labour to control them. Indeed, from the tool setting point of view, Swiss automatics are often much more simple than capstans, once the principles on which the machine operates are understood.

Automatics, in recent years, have developed into highly complicated machines and on the turrent and multi-spindle types much of the mechanism is hidden from view. In its belt driven form the Swiss type of machine remains essentially very simple in design, and every part of it is readily visible. It is, thus, much less difficult for engineers with no previous experience of automatics to become acquainted with the use of this type, than any other. Owing to the fact that relatively fine feeds and high speeds are used on these machines, they are particularly well adapted for the use of hard metal tools, especially turning tools, which being of the side cutting or knife type, are easily ground. These tools may be found without rake or lip, which simplifies their application still further. The close proximity of the support is also of considerable advantage in this respect.

The machine is arranged with one pair of tools rocking on a transverse holder and either one or two tools guided by dove-tail slides and independently controlled. By advancing the spindle nose through the bush holder (after removing the bush), it is possible to arrange for several operations to take place simultaneously on pieces which are relatively short in comparison to their diameter,

and it is to be observed that this machine is built with spindle bearings of sufficient capacity to allow this method to be exploited to a high degree. Thus, a piece may be screwed or drilled while it is being cut off and at the same time a second piece may be shaped behind the cut off tool by one or more form tools. This method can be followed with very consistent results, owing to the extreme accuracy with which the machine feeds out the necessary length of stock.

Maintenance of Swiss type machines is simple and straightforward. The component parts which are liable to wear or breakage are very simple and accessible, and can therefore be rapidly renewed or replaced when necessary. In the majority of cases they are capable of being made without great difficulty or the use of expensive plant, and the total number of such parts being small, a large stock of spare parts is not called for. The elimination of the feed finger by means of the weight feed also makes for economy in running cost.

The Turret Type.

Swiss type automatics produced by different makers are all very similar in design, the main difference being in the number of tools which are grouped around the bar of stock being worked.

In the case of turret type machines, however, very different applications of the same principle are to be seen, and it has been thought fit to include under this heading certain machines which have no turret at all, this being replaced by a simple tool-holder.

This has been done because the most popular type of turret automatic to-day can be furnished as a simple three operation machine merely by omitting the turret with its mechanism and mounting on the same slide a simple tool. Where only three tools are required this has the advantage of decreasing first cost. The type of machine referred to is that in which the turret is mounted on a horizontal axis at right angles to the spindle so that when it is revolved in an anti-clockwise direction the tools are presented consecutively in line with the main spindle of the machine. This design, in conjunction with two or even three cross-slides and an independent swinging stop is acknowledged to be the most universal and versatile type which has so far been evolved, and the result of many years of concentration by designers in this country, the U.S.A., and the Continent may be seen in the highly developed examples offered to-day.

The great advantage available on this type lies in the opportunities offered for the development of special attachments both on the cross-slides and turret, and also in what may be termed the external position, that is, mounted on the machine but working independently of the regular turning tools after transference of the piece from the machine spindle to the attachment. It is now possible, by means of cleverly designed attachments, to produce work easily and

accurately and at high speeds on turret autos which would be commercially quite impossible by any other process.

The turret machine will be considered first in its simpler form, i.e., the belt driven type. The bar of stock is carried in a spindle which is driven by two belts from an intermediate shaft which in turn may be driven at two different speeds. Either or both belts may be crossed or opened and the ratio of the speeds applied to the intermediate shaft may be varied by changing the main drive pulleys. The spindle belts may also be arranged to drive the spindle at different speeds direct from the intermediate as well as in opposite directions. The two pulleys on the spindle are free to revolve on it except when the clutch, which each contains, is engaged. If the belt is removed from one pulley and a clamp provided instead, a spindle brake becomes available. The selection of the speed or direction of drive is accomplished by mechanism controlled by dogs capable of being set to operate at any point in the cycle of operations. A wide choice of combinations of spindle movement is therefore available as follows : Spindle forward at two speeds, backward at two speeds of any ratio to the forward speeds, within the capacity of the clutches. Forward full speed and at three other ratios, two of which are factors of the third. Forward at two speeds and stop. Backward at two speeds and stop.

When these speed ratios are used in conjunction with a self-opening diehead, it becomes possible to automatically select cutting speeds which are exactly suitable for each stage in the production of a piece so that each and every tool may work at the most efficient rate. Milling attachments may also be used when the spindle is arranged to stop, although it will be appreciated that in this case only two speeds and one direction are available. The deficiency, however, is again overcome since threading tools may be mounted in the turret and revolved in either direction.

There is an evergrowing tendency nowadays to build the turret auto arranged for direct motor drive. Some manufacturers actually build no other type. While the advantages of this method are more obvious in the case of automatics than other machine tools, it should be kept in mind that a certain amount of flexibility is lost by this arrangement owing to the fact that the ratios of the various speeds available are controlled by the design of the gear-box and cannot be altered easily. To obtain the maximum degree of flexibility in the plant it is therefore recommended that a certain number of belt driven machines be incorporated, even if special provision has to be made for the countershafts. In this connection it is desired to draw attention to the advantages which may be obtained by the use of hard metal tools. When such tools are used on automatics, it is nearly always found that it is necessary to use

certain tools of high speed steel in conjunction with these. In the case of the combination of a roller box with hard metal tool, working in conjunction with a self opening die-head in the production of a bolt or screw of alloy steel, it is found desirable to use a ratio between turning and screwing speeds of as much as ten or twelve to one. Such ratios are easily arranged on the belt driven machine and a third can even be included to deal with forming operations, whereas the motor driven machine would reach an impossible stage of complication were such wide ranges attempted.

The cross-slide tools used are usually of the circular type, and the only limit to the variety of shape which may be achieved with such tools is the ability of the piece to stand up to the strain imposed by length of cutting edge. When the piece is finally separated from the bar it may be gripped by a swinging arm and transferred to an external attachment and work performed on it while a second piece is being dealt with by the machine proper, being finally ejected and led away to a separate compartment so that it does not get mixed up with the chips produced.

Consider a piece, the outside shape of which is such that jigging after turning is a difficult matter. The following operations may be performed: The piece may be turned, countersunk, drilled, and tapped, keyways may then be cut on the turned portion or grooves cut in the end face. It may then be crossdrilled in relation to these keyways, formed to shape, cut off the bar and transferred to any attachment which may mill or thread the other end; back countersink the hole; or perform further crossdrilling with or without indexing, and all these operations are performed at the correct speeds and feeds previously decided upon, without any attention other than the maintenance of cutting tools and stock supply.

It would be quite impossible to describe the tremendous variety of equipment which has been developed for use in conjunction with the turret type of automatic, particularly since much of the equipment is of most intricate design. Nearly every keen engineer who has occasion to take up the study of this machine eventually develops some equipment particularly suited to his class of work, with the result that the field of knowledge in this particular branch grows constantly larger

While the turret type automatic scores heavily in the field of intricate production. it must not be overlooked as a means of obtaining high production of more simple pieces.

The accepted standard is a turning length of approximately three times the rated diameter capacity, and within this range the same machine may be used to produce a very wide variety of parts, The tools and cams for each part being produced in advance, it is a simple matter to change over from one piece to another, and very little production time is lost whilst this is being done.

For example, it is possible to set up the machine to produce a 2 BA bolt $1\frac{1}{2}$ in. long in about one and a half hours. This job will take approximately eighteen seconds. One thousand will be produced in six hours, allowing for feeding. The machine may then be changed over to produce a brass nut to suit in, say, another one and half hours and these nuts being produced in three seconds each will take about one hour to complete. Thus, in ten hours the machine will complete an order for 1,000 nuts and bolts without difficulty; and special variations of such articles, may be produced with equal facility. A group of such machines is of the greatest possible value in an organisation where special variations of an assembly are required at short notice.

The question of quantities is one that enters largely into the economical running of automatics, and the stage at which any particular piece ceases to become a capstan job and becomes a proposition for the automatics is one which constantly gives the production engineer food for thought. It is not proposed to go deeply into this question here, but it is desired to draw attention to a point which is often overlooked. When a small batch of work is to be produced, it is often classed as a capstan proposition on quantity alone. Such jobs all too frequently go to the capstan department and are left to the discretion of the setter as to the method of attack. At the same time these quantities are often small because they are of an experimental nature, whether in design or material. If the requirements of the parts as regards finish and accuracy are known, and the specified material is also known, cams may be prepared which will give the required result exactly on an automatic and it has been found that this apparently expensive way of producing an experimental or special order is the cheaper in the long run, simply because the results and costs can be accurately determined beforehand, and usable material can be delivered with certainty. This suggestion is offered as a possible solution to a problem which in many organisations is of vital importance.

In the matter of screw-cutting, the turret type automatic can offer facilities not to be found on capstans. The rate of feed in relation to spindle revolutions can be determined accurately by the cam designed, with the result that a die may be fed at exactly the right speed for the pitch of thread being produced, thereby avoiding such discrepancies in thread formation as appear when dies are handled by unskilled operators.

The dimensions of the parts suitable for producing turret autos often demand the use of very delicate tools. Such tools depend to an enormous extent on a regular feed of the correct amount, and when used on hand-operated machines are just as frequently spoiled by over cautious operators as by rough usage. Both these difficulties are overcome when they are used on an automatic,

since the feed is always the same and is predetermined.

In the foregoing remarks it will have been noticed that many of the benefits which may be derived from the use of turret machines depend in the first instance on cam design. This question is of great importance, since each different piece to be produced on the machine must have a cam layout designed for it beforehand, and it is equally serious if they are laid out to produce the piece too slowly or too quickly. The former may lose the order, and the latter will most certainly lose the profit.

Only two satisfactory solutions are available. Where a few machines only are installed, it is better to take advantage of the service offered by the suppliers and have the cams and tools designed and made by them. When the installation reaches larger proportions, it is necessary to give every possible facility to an individual who in the first instance is a practical man, with full knowledge of what may be expected from various designs of tools used. The operation of automatics continually attracts workmen of the better type, and it is not difficult to select a man with sufficient keenness and to give him the necessary facilities for acquiring the technical knowledge required in the construction of cams. On the other hand, it is almost impossible for a technician to acquire the practical experience which is so desirable.

Mention must be made of the other types of turret machines at present available. These include the type with turret revolving on a vertical axis. An important advantage of this system is that the turret mounting lends itself readily to an oscillating movement. This enables a somewhat cheaper machine to be built which may in certain cases be faster in operation than the fully universal type already discussed.

A further type, again, is arranged with the turret axis parallel to the spindle axis. In this type the turret is developed to a much greater size in relation to the other parts of the machine and is arranged to rotate and slide in its bearings. The immediate advantage is that pieces may be turned having a much greater ratio of length to diameter than has previously been mentioned. This type is arranged to have motion transmitted to the turret by one cam which is used in turn for each tool being driven at automatically varied speeds to suit. The machine is heavier in construction and slower in operation, but it is very dependable and has a long working life. More machines can, in consequence, be given to each setter, so that production costs do not necessarily increase by any great amount. There are also certain types of turret machines having special features incorporated in order to make them particularly suitable for certain special operations, but it is felt these come outside the scope of a general survey.

Multi-Spindle Automatics.

Very little consideration is required before it is obvious that the production value of an automatic can be considerably increased by designing it in such a manner that several bars of stock may be worked upon simultaneously, and machines have accordingly been designed from time to time having two, four, five, six, and recently, even eight headstock spindles. Of these the best known and most widely used is the four spindle horizontal type which, first introduced some forty years ago, has recently undergone very considerable improvement in design, and is now offered in a very highly developed form. In this design the spindles are grouped in a cylinder around a central drive shaft which imparts constant rotary movement to each through a single gear rigidly mounted and mating with a single master gear on the drive shaft.

The cylinder is arranged to be rotated through 90° at the proper time by a geneva motion mounted on the main camshaft of the machine. Opposite each spindle is mounted a tool or tools on a common turret or bed which has only one motion, i.e., towards and from the spindle nose. A cross-slide is also mounted at a convenient angle to each spindle. On the advance of the tools the first operation takes place on the stock which is in position opposite to the first operation tools, mounted on the turret or tool slide. When the operation is complete the tools are withdrawn, the spindle cylinder is rotated, and the stock which has already had the first operation performed on it is now opposite the second operation tools, the tools being, of course, arranged in sequence in the same direction as that of the rotation of the spindle cylinder. The sequence is thereafter continued, each piece being cut off as it reaches the fourth position, a new length of stock being fed out as the spindle is rotated to the first position again.

The camshaft is rotated at two speeds, a fixed high speed for the withdrawal of tools and rotation of spindle cylinder, and a low-speed variable by gearing for the feed of the tools. Above the main tool slide are auxiliary slides in which tools may be mounted which require rates of feed different from the main tools, and these slides are moved by cams of different shapes and timing relative to the main cam actuating the tool slide. Screwing is accomplished by rotating the die in the same direction as the work spindle at a ratio speed either above or below that of the work spindle, according to the hand of the thread, the ratio being reversed at the appropriate time in order to run the die off.

The tools mounted in other positions on the turret may also be revolved by auxiliary spindles to compensate for the different cutting speeds required by different tools. All the motions of the machine are positively driven by gearing from a single pulley main drive. The general arrangement of work head stock at one

end and tool slide and gearing at the other, enables a well-balanced machine to be produced, with the separate units well braced together by the oil tank base, and a main backbone casting at the top.

Several outstanding advantages are apparent. The production time for any piece is the time required for the longest operation plus the time required to withdraw tools and rotate spindle carrier. No more than three or four standard cams are required for the main tool slide, each cross-slide, and auxiliary. The spindle speed can be adjusted as required by pairs of pick-off gears, and at the same time the screwing speed can be permanently arranged on a very low ratio without affecting the output. By the use of compound pick-off gears the feed can be adjusted in very fine steps. Owing to the fact that four robust cross-slides are available, elaborate forming operations may be carried out with simple tools. Predetermined caming is not necessary and this, in conjunction with the last-mentioned item, helps to lower the overhead expenses.

The indexing and locking mechanisms are very substantial and work under conditions of leverage relative to the cutting tools, which give every possible advantage. The tool slide or turret presents a wide area for the mounting of tools, so that tandem applications may be made. This enables the machine to compete with, and in some cases even surpass, the single spindle machine with six-hole turret and three cross-slides when complicated setups are required.

The four spindle machine lends itself in a high degree to the production of pieces by extensive forming from the cross-sides, particularly in the case of the design in which the main tool slide is supported on a rigid extension of the spindle cylinder. A steady, or support, for the bar can be arranged on this type in such a manner as to be absolutely rigid relative to the work spindle, with the result that forming cuts of enormous length can be made with precision. The chief reason for the remarkable capabilities when forming, however, is found in the opportunities available for the incorporation of very active slides, these being arranged round the spindle cylinder, which, being relatively large, allows plenty of room for their development. These facilities for expansion are also of great advantage in set-ups of a more specialised character, and although elaborate tooling is not desirable on machines which are subject to frequent change over and short runs, where conditions warrant, tooling can be readily devised for dealing with the most complicated operations. In some designs the versatility of the machine is increased in a similar manner to the single spindle machines already discussed by arranging a clutch inside the spindle drive gear, so that the spindle may be stopped when required for milling operations to take place. In one recent design this scheme has been carried

so far that it is possible to turn pieces in one position, and in the next position rotate the spindle at a speed suitable for thread milling operations, which are performed by an auxiliary unit mounted on the upper slide.

It will be seen, therefore, that the multi-spindle may be worked as a simple machine for jobbing work, in which case very little toolroom or drawing office service is required, or when occasion requires, may be developed for special jobs to an almost unlimited extent. The advantages and experience gained on the four spindle automatic have led designers to study the possibilities of increasing the number of spindles still further. The five spindle machine has been available at different periods in the past, but the modern tendency is towards machines having six or eight spindles.

While the geneva motion is in itself shockless the indexing of a multi-spindle head is not quite so perfect as could be desired, owing to the fact that whip is liable to be set up in the stock reel, causing a certain amount of slap.

With the increase in the number of spindles, the arc through which the spindle cylinder has to be indexed decreases, being 90° for four spindles, 60° for six spindles, and 45° for eight spindles. The acceleration and deceleration during the movement consequently becomes less severe and the effects of whip become less to a marked degree. This is so much the case that a six spindle machine working alongside a four spindle machine of the same size appears to be working at a very much slower rate, although the cycle time is little more than half that of the four. This absence of " fuss " must obviously have considerable bearing on the life of the machine.

One important consideration when dealing with design of multi-spindle machines is the stock feed arrangement. In order to reduce as far as possible the idle time, the movement of the stock feed mechanism is allowed to overlap that of the spindle cylinder. This introduced problems in regard to the movement of the stock feed tubes and the design of cams to produce this movement. As the number of spindles increases the spindle cylinder movement decreases and a much more satisfactory stock feed can be obtained for the same total of idle time. When eight spindles are incorporated a still further improvement can be affected. The use of eight spindles to produce one job is very rarely required, but by arranging for the stock to be fed out in two positions simultaneously when required, the eight spindle machine can be used as a " double four " ; the tools set up being, of course, arranged so that the second four positions are duplicates of the first four. The full capacity of the machine can then be used on more simple jobs, two parts being produced together. This is frequently more satisfactory than the ordinary method of producing two or more parts

per cycle with only one feeding position, owing to the decreased length of stock feed.

One difficulty connected with multi-spindle machines is that in the horizontal arrangement the design must necessarily be to a certain extent unsymmetrical. This sometimes causes difficulties in use by reason of the fact that operations cannot be performed in the sequence most suited to the product. An attempt to overcome this has recently been made by the introduction of a machine with six vertical spindles. In this arrangement the design becomes naturally symmetrical, with the result that each spindle position can be equipped with exactly the same type of cross-slide, working at the same angle and all the end working stations are also identical. This means that any operation can be performed in any position, and the machine can be tooled to produce a part by the most suitable sequence of operations.

Many other advantages are obtained also. It is a simple matter to feed the stock in one, two, or three of the available positions. All tools and tool holders are interchangeable as between one position and another. This means that the correct number of stations can nearly always be used for any given job, and that the number of special tool holders of different types can be decreased. Also, every tool at every station is equally accessible and the setter can remain in a vertical position to a very much greater extent while making adjustments. The effects of inertia in the spindle cylinder and bar support arrangement are of a different order, showing a considerable improvement, and the difficulty of arranging the relative movements of the spindle cylinder and stock feed tube, discussed previously, is entirely overcome by the elimination of the tube, stock feed being by gravity. It is hardly necessary to add that economy in floor space is also shown.

One interesting application of this machine is in deep drilling and long turning behind shoulders, a combination not infrequently met with. When deep drilling is required the drill must be withdrawn from the hole at frequent intervals. In the horizontal position chips are liable to remain in the hole when the drill is withdrawn, being pushed to the bottom and jammed between the cutting point and the wall of metal being attached, on the return of the drill. With a vertical drill cutting in the upward direction this danger is almost entirely overcome, thereby removing the cause of the frequent breakage so generally experienced in this class of work.

In turning behind shoulders, advantage is taken of the ease with which the cross-slides can be arranged for compound working and mention must also be made of the facilities for profile and taper turning which are obtainable for the same reason. A whole paper

could be devoted to the examination of this type of machine and its applications, many of the most interesting of which are outside the scope of the present paper.

From the foregoing, it will be seen that the bar automatic has been developed very considerably and it is to-day a machine able to deal with a range of production operations covering a very wide field. The greater part of this development has taken place in foreign countries, and one of the most interesting and important fields in machine tool design has been largely neglected in this country. In certain other cases machines produced in Britain can be offered to the world as leading in design and performance, and it is felt that further time should not be lost in exploiting the possibilities of new designs of automatics.

What has been done up to the present is small compared with what must follow, and there is still time to add important achievements in this direction to the record of British machine tool engineering. Machine tool designers, however, must be guided in their researches by the requirements of the production engineer, who can further this end by introducing his ideas and suggestions to the machine tool specialist.

The limitations of present designs should be considered as well as their virtues. We are still without infinitely variable spindle speeds ; or collets and feed fingers still cause trouble and delay ; and we still have to make and replace cams. Hydraulic operation has not yet been applied to automatics, and the vertical machine is in its infancy. Even the friction clutches employed are waiting for real development, and the use of hard metal tools is restricted by design.

The solution of any one of these problems would place British built automatics in the front line, but the machine tool builder must know what is required before he can provide it and this knowledge is only be be obtained from the user.

In conclusion it is desired to draw attention to the benefits which could be obtained by encouraging the study of automatics in technical schools as the subject possesses scope which is far greater than the few applications discussed in the present paper.

Good results from autos depend largely on the class of operator available, and with the ever-growing use of automatics, recruits are constantly required in this class. This difficulty may be met in two ways. The first and more general way is to take boys from school and employ them as feeders, allowing them to acquire the necessary skill from the setters under whom they work. This system frequently leads to the evolution of a type of workman who can grind and set tools but who has little or no real knowledge of the function of the various parts

of the machine. The second method is to recruit labour by transferring youths from the tool-room, after they have acquired sufficient knowledge to be regarded as, first, potential engineers, or, secondly, potential tool setters. By this means the operator is given a broader outlook and is more capable of coping with the developments in the machines which are constantly taking place.

THE INFLUENCE OF TRADITION ON DESIGN.

Paper presented to the Institution, Birmingham and Yorkshire Sections, by R. G. Hewitt, A.M.I.P.E.

Introduction.

IN presenting this paper I wish to make it clear that as the subject is a matter of opinion and not of fact, the conclusions arrived at are bound to be controversial. In the purchasing of new machine tools, after allowing for all the various factors such as price, output etc., there is a subconscious tradition bias which influences more than is realised the final selection. It is this psychological aspect of tradition that I have tried to make the background of the paper. I have tried to show that whether we are designers, production engineers or mere cogs in the wheel, we are, after all, only flesh and blood with tradition firmly rooted in us.

At the end of the paper, in attempting to define the possible future trend of machine tool design, I suggested that speed variation, dependent now mostly on an elaborate and expensive gear box, will probably be obtained more and more by means of hydraulics and electricity. Since I first wrote this a machine without gear box has been developed ; I therefore include it.

Tradition is generally regarded as something to be venerated and esteemed, having been achieved after long years of experience and handed on by the wise to those that follow after, becoming a kind of golden rule always good and always to be followed. The object of this paper is to show that the influence of tradition on design in the past has not always been good, but that it has often retarded progress and hampered design. Certain types of machine tools have been kept in existence that changing conditions have made, if not obsolete, at least inefficient. Further, it has caused a time lag between the introduction of any beneficial invention, method of idea and its general adoption in industry.

The influence of tradition on design has not received the attention it deserves. So many influences affecting design have been brought to our notice, that this important factor seems to have been overlooked. It has been stated that the machine, like a woman's dress, is influenced by fashion and that change for change sake has often been the cause for alteration in design. Far more probable

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Birmingham, December 18 ; Leeds, January 21

is the claim that intensive production has materially affected design, bringing into existence the unit machine tool, single purpose machines and highly complicated machines with many tools cutting at once. Again, the application of electricity to the machine has simplified design in most cases, and the use of hydraulics is exerting an ever increasing influence. Furthermore, it is claimed that the introduction of cemented carbide tools has brought about such revolutionary changes in design that they have exerted the strongest influence of all. Finally the steam engine, locomotive, bicycle, internal combustion engine, the Great War, motor cars and aeroplanes, have all in their turn influenced design. But whereas their influence denoted the successive stages in the evolution of machine tools, the full measure of their beneficial effect on design has often been retarded by tradition.

Examples of Tradition's Influence.

The dictionary defines tradition as " The handing down from age to age of the customs, ideas and beliefs of a community." In industry it can be defined as the handing down of accumulated ideas and experiences, and it is often known as " accepted practice," traditional methods that have been acquired after years of experience.

Unfortunately, most of the ideas and experiences that were so successful years ago cannot now be applied. That is why older engineers brought up on steam driven ships did not want the diesel engine, and, later, when the diesel engine had become widely used did not want electrically propelled ships, because they had no experience of the newer methods. Or, as a technical journal recently stated about railway engineers, " The conversatism on the railways towards improvements is probably the result of their early training."

It is also true that in spite of our educational and technical training we have all a strong technical bias in one direction or another and we all possess in a greater or lesser degree ideas hallowed by tradition. Until quite recently the traditional heat engine occupied a prominent place in technical education, but, thanks to the initiative of the Institution of Production Engineers, far more essential subjects are now being considered. When Dudley introduced smelting by coal in 1620, tradition, represented by the other iron masters, tried every means to prevent the sale of his iron and eventually succeeded. Later, Abraham Darby was called " iron mad " because he maintained that iron could be used for building not only bridges but ships.

The bitter opposition to the introduction of the railways and the objections raised by many learned gentlemen seem to-day petty and childish, yet so strong was tradition that it was not until 1896 that the law insisting that a man with a red flag should precede mechanically propelled vehicles was repealed. In those cautious

days the speed limit for mechanical road vehicles was two m.p.h., surley a laudable example of safety first. It is interesting to note that the early motor cars were similar in appearance to the horse drawn vehicles. The engine taking the place of the horse was placed in front and remains there even to-day, when presumably it would be better nearer the driving wheels. When horse-drawn trams were replaced by steam and electric trams, years elapsed before glass windows were introduced to afford protection for the driver against the variable English weather.

Another notable example of tradition was the time it took to convince the War Office of the merits of the tank in the early days of the war. It has been stated that so great was the opposition to this new " mechanical toy " that even when they were finally allowed to go into action the whole affair was so badly handled as to spoil any element of surprise to the enemy.

In 1840 Whitworth suggested a standard screw series, but it is only in recent years that standardisation has been taken seriously. When electric drives for machine tools were introduced most engineers regarded the innovation with grave doubts, and although Crompton as early as 1894 successfully applied individual motor drives to machine tools, many years elapsed before they became generally adopted. Hand scraping, attributed to Whitworth, is still in some cases relied on for the accurate finishing of machine tool slides. In fact, it is still claimed by some American tool builders that as it is impossible to grind a surface absolutely plane, hand scraping is relied on to remedy the defect. Tradition has therefore played no small part in retarding the modern method of grinding slides, and the verdict as to its improvement over the older method is by no means decided.

Flanged motors for machine tools were first standardised in Germany, but it was only after a considerable time lag that their value became universally appreciated. The same can be said of the application of roller bearings to lathe spindles. Their introduction aroused considerable criticism, and it was only gradually, after a time lag of over fifteen years, that roller bearings became accepted practice in lathe spindle design.

The protection of machine slides, especially on turret and centre lathes, and the need for greater chip clearance, have been evident for fifty years. But as it was the " accepted practice " to make machines without these refinements it needed the cemented-carbide tools to overcome tradition.

The application of hydraulic transmission to machine tools is no modern innovation, but considerable time elapsed before its advantages became appreciated. Although hydraulic transmission to broaching, grinding and milling machines is in the process of becoming hallowed by tradition, the advantages of the hydraulic

motor when applied to lathe spindle, etc., is still a matter of considerable controversy. On the one hand you have an infinite speed variation and a smooth drive without vibration, while on the other hand you have a certain loss in efficiency and a considerable increase in first costs. In the electric motor, however, the torque decreases as the speed of the motor is decreased, thereby reducing its efficiency, whereas in the hydraulic drive the reverse is the case. It seems fairly evident that where a flexible positive drive without vibration is required, the hydraulic motor unit would be an ideal form of drive to use. This form of drive, however, is making but slow progress, the critics stating that this is owing to the high initial first costs and to its being limited to light or medium loads.

The widespread adoption of Vee belt and Tex-rope drives in recent years on almost all types of machine tools after electric motors of the flanged and built-in types were becoming more widely used, is disturbing, being almost like a return to the old belt and cone-pulley drives. We find large turret lathes, drills, and even large boring mills, with this kind of drive. After making numerous inquiries I found the reasons were in the first place to cope with the enormous increase in speeds now required; simplicity and cheapness were also mentioned, but the most important factor was elimination of vibration. One authority on machine tools went so far as to state that it is almost impossible with a gear-drive to eliminate vibrations at high speed.

Built-in motors were also mentioned as being unsuitable both from the standpoint of vibration and because no motor is free from trouble. Flexible drives with a motor mounted apart from the machine were advocated as having a damping effect on vibration. These are excellent reasons, but we can also see traditional influences that could be overcome. Take the case of electric motor causing vibrations. Surely this is but a question of balance, and something that could be overcome. Were I an exponent of gear drives I could prove that gears could be made that will not set up vibrations when running at high speed. This increasing demand for flexible drives without vibration is in my opinion the main argument why eventually the hydraulic motor will become more widely used. Having thus indicated the influence of tradition in a general way, let us consider in more detail its influence on design.

Evolution of the Lathe.

The lathe is one of the oldest types of machine tool, its origin going far back into antiquity. In its early primitive form it is still in use in India and other countries, where the head stock and tail stock are posts driven into the ground, and the centres are iron pegs driven through posts into work. The workman supports

the tool with his toe while his foot is guided by a rail in front; these combined make the tool post and sliding action. A small boy supplies the motive power. Here, then, are the fundamental principles of the lathe and in this simple form two factors control its design: First, that it should be in a horizontal position; second, owing to the workman's position, the work should rotate in an anti-clockwise direction.

The development of the lathe was slow and in 1680 we find Moxon saying: "High-class wood work could be done in a lathe and nothing more." It was not until 1772 that particulars of a lathe with slide rest was published in a French encyclopedia, although as early as 1741 Hindley, a clockmaker of York, made a small screw cutting lathe having change wheels.

Pole Lathe.

A pole lathe, made about 1800 and used by Noakes & Sons, Ltd., London, until 1879, for turning barrel cocks, indicates the next stage in the lathe's development. The bed consists of two oak beams a few inches apart, mounted on two posts fitted with feet for fixing to the floor, and the head and tail stocks are massive blocks of oak, the headstock being fixed by a wedge and the tailstock adjusted and clamped by the bolt in any position along the bed. The rest, shaped to clear the work, is clamped to the bed. The pole consists of a straight bough of a tree supported on a cross bar near the middle to provide for lateral adjustment. A driving cord is attached to the free end of the pole and passed round mandril, on which is located work, and down to the treadle below. On pressing the treadle the work is rotated in an anti-clockwise direction when the turning would be done. On releasing treadle the spring of the pole pulls it upward causing mandril to rotate in the opposite direction. Similar lathes are still used by the chair makers of High Wycombe and in Oxfordshire. This particular lathe is in the South Kensington Museum, lent by Noakes & Sons for exhibition.

Maudslay Lathe.

The real foundation of the modern lathe, however, was laid by Maudslay, who made the first lathe with a travelling saddle about 1794 and in 1800 put a lead screw and change wheels on his lathe. The bed consists of two triangular wrought-iron bars secured at each end in gun-metal brackets. The head and tailstock are fixed to the back bar only, but the slide rest, made of gun metal, slides on both bars and carries a vee cross-slide operated by a screw fitted with graduated disc.

These remarkable improvements revolutionised turning and signalised the first great transfer of skill from the man to the machine, as this slide clearly indicates, while they also swept

away the two fundamental factors of the primitive lathe, namely, that a lathe should be in a horizontal position and that the rotation of the spindle should be anti-clockwise. And yet it was round about forty years later that the first vertical turning machine was designed, and 130 years later before a lathe with a clockwise rotation of spindle was introduced. Maudslay's screw cutting machine laid the foundation of a standard screw thread system, which was extended by J. Clement, and finally established as a national system by Whitworth.

Maudslay Screw-Cutting Machine.

There is at South Kensington Museum a small example of the original invented about 1800. It is driven by hand-power, the screw to be cut being held between centres, and the saddle is fitted with travelling steady. The screw cutting tools include both single and multiple point tools.

Roberts' Lathe.

Richard Roberts, who had been in the employ of Maudslay, started building machine tools in Manchester in 1817. He evidently found that the triangular wrought-iron bed used by Maudslay was too weak, for he immediately started making a lathe with a cast-iron box section. The lathe, which is preserved in the South Kensington Museum, is worthy of note as the first example with back gearing with the cone pulley loose on the spindle, which soon became standard practice, and an arrangement at the tool end to take spindle end thrust. The saddle of Roberts' lathe is traversed by a long screw at the front of the bed, which is driven by a variable feed gear from the spindle. Both the design of tailstock and tool post became accepted practice and the ornamental curved legs soon became a legacy of tradition. This ornamentation of machine tools became for a time so pronounced that we find in 1893 " Lodge and Shipley " machine tool builders of America advertising a lathe of new design and stating that " ornament, as such, has been dispensed with. The real outlay is in the accuracy and working parts."

The greatest of the men associated with Maudslay was J. Whitworth, and he dominated the engineering of this country for many generations. Starting as a tool maker in Manchester in 1833, in a few years he was turning out lathes, planers, shapers, and drilling machines of great power and variety.

Whitworth Lathe.

A lathe built by Whitworth in 1842 is still working at Soho Foundry, Birmingham, and we are all familiar with the design both of the headstock gearing and the feed and reversing mechanism. When this machine was first built it was equal if not superior to the demands made upon it, and it became the traditional

design for the next seventy years. In 1850, Whitworth was the most advanced machine tool builder in the world, but about this time he turned his energies to armaments and no marked progress was made in lathe design in this country for some considerable time. It was in America that we note the next stage was reached when Wendell P. Norton invented the quick change gear arrangement which appeared on the "Hendey" lathe in 1892. There was considerable time lag before any such refinement appeared on lathes in England. In 1856 the first capstan was built in America by Robbins & Laurence. The lathe over there was already beginning to be displaced.

In ***Machines and Men***, W. F. Watson, who writes after working on an American lathe for the first time round about 1903, says "British lathes were world famous, they were spendidly built of first class materials, but entirely unsuitable for quick repetition work. They were too heavy, too awkward to manipulate, the bearings were small in diameter, short in length, and altogether out of proportion to the heaviness of the build. As a matter of fact they differed very little from the first metal screw cutting lathe designed by Maudslay. Though lightly built, American lathes have bigger and longer bearings, they carry many time saving gadgets which made them easier to handle, and they are much more reliable for accurate work. Why British machine tool makers did not step in with similar improved lathes and labour saving machinery has been a source of wonder to me. The fact that mass production began there may account for America being first in the field, but it does not account for British makers continuing to make obsolete machines, nor does it explain the average engineer's prejudice against American machines. It can only be explained in traditional conservatism." It is only fair to add that Mr. Watson later in the book, referring to about 1920, says "To-day British produced machines are comparable to anything imported from abroad."

Comparing the Whitworth lathe with a Darling & Seller lathe built in 1910, there are only a few minor alterations; the lead screw has been brought to the front again, as on Roberts' lathe, and the feed mechanism has been altered. It can be said, in a general way, that most machine tools sixty years ago began to assume their present day form, with some turret and capstan lathes in evidence.

Such, very briefly, is a resumé of the lathe's development during the years it held the place of honour in the workshop, but new machine tools were gradually being developed and one would assume that the importance of the lathe has decreased, but this is not the case. In 1934, lathes constituted one-third of the total British exported machine tools, and while no new lathes except bench lathes were put out by American manufacturers in 1934, thirteen new designs were announced by European firms. In a recent inventory

of American metal working equipment there were in existence 170,000 bench and engine lathes (including tool room lathes), of which 70% were over ten years old, compared with 73,000 turret, capstan lathes and vertical turning machines, 65% over ten years old. Could such an inventory be taken in Britain, the results would be even more appalling. So the lathe, besides influencing the designs of most machine tools, still predominates in the workshop, thanks to our early training on it, and traditional influences, causing perhaps, machines of the horizontal type to become an obsession and retarding the progress of vertical type machines.

If it be true that demand creates the supply, then the buyer and not the builder of machine tools is the greatest adherent to traditional methods as the following story indicates : An American farmer drove up to a modern car depot where the latest models of streamlined cars were on view and told the salesman that he wanted to buy a car. The salesman with considerable pride showed him the best in the place, and went on to extol their respective merits. The farmer listened unmoved until he had finished, then taking him by the arm led him outside to where an old 1897 model stood shivering from the vibrations of its ancient engine. The farmer, pointing a finger, said with determination, " I want a car, a good car, just like this one here."

Comparisons between vertical and horizontal machines.

As far back as 1875, vertical boring and turning mills were being made in America. The first boring mills of British origin date even farther back, and were made by Bodmer in Manchester in 1838-39. For many years this type of machine was used only for heavy and awkward jobs, seeing that it was easier to lay a job down on the table than hang it up in the lathe chuck, and on these early machines the influence of the lathe was strongly marked. The uprights were of slender design and cone pulleys and back gearing made it look like (as it really was) a lathe placed on its end. The machine illustrated was built by Samuel Lund, of Keighley, about forty years ago and is still in use. Alteration to table speed is attained by cone pulleys and back gearing, the counter shafts being fixed to machine housings and power is derived from motor fixed to floor with belt drive to countershaft. Two features worthy of note are : Coil springs are utilised for balancing the tool post, a feature distinctly modern in character and the left hand tool post has been designed to take thrust caused by tool under weight of cut, which is obviously in the reverse direction to the right hand tool post, a feature which, curiously enough, is often overlooked on modern machines. The slender proportions of table and the small and limited service of chuck jaws are indications of the machine's

age, as is also the squealing belts when cutting is in progress. Considering this machine from the standpoint of output and efficiency, the proper place for this relic is a Museum.

Brake Lathes.

Quoting from an old boring mill catalogue, "Faceplate, or brake lathes, were originally made by leaving off the tailstock from a regular engine lathe. Had the brake lathe been built before the engine lathe, we venture to say that it would have been made vertical." Another example of the traditional influence of the lathe. Except for special jobs, such as retaining the tyres of railway

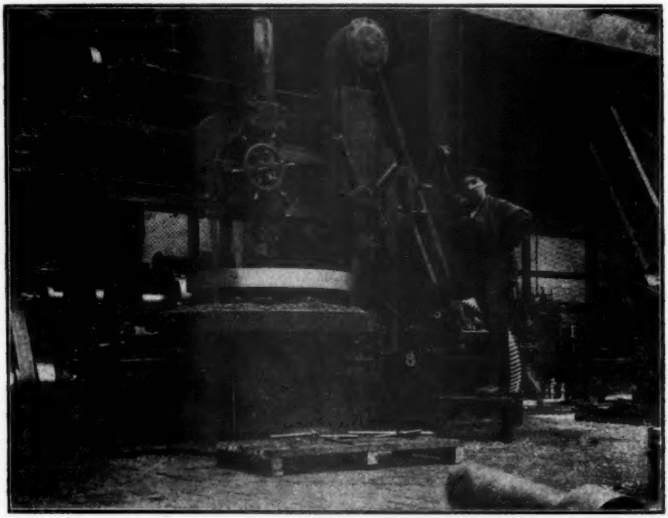

Fig 1.—Samuel Lund, Keighley, Vertical Boring Mill.

wheels in position on axle, etc., one marvels at the continued survival of this type of machine tool, when work can be done in considerably less time by a machine occupying only one-third of its floor space. For example, nine or ten years ago there appeared in *Machinery* a description of a brake lathe for turning flywheels 5 ft. in diameter, which were completely finished in three hours fifty minutes. This machine was provided with five cutting tools, all of which may be in operation simultaneously, while the entire machining operations were carried out at one setting. Being convinced that this time was no remarkable performance I timed the machining of a 5 ft. 6 in. flywheel, 7 in. face width on a vertical

boring mill. This was done in two operations in a total time of two hours fifty minutes, thirteen minutes of which was spent in lifting with crane and two " settings up " of work. Only two tools were cutting simultaneously. The average cutting speed was 55 ft. per minute and the longest operation was forty minutes in machining the bore. At a recent lecture before the Institution of Production Engineers it was stated that machines of the vertical type, which aim at space saving, have made little progress, a statement which is hardly correct, since most of the revolutionary improvements in design during the past few years have been on machines of the vertical type, such as Lund's surface grinders, Ryder's vertical lathes, Gyromatics, Bullard's and Ryder's vertical autos, Wicke's vertical broaching lathes, and many others.

Soderman & Stiers 24 in. V.T.L.

Space saving is not the only advantage of the vertical turret lathe. Operators' fatigue, swarf disposal rigidity, more powerful drive, reduction in setting time, and higher output, need only be mentioned.

Operators' Fatigue. Although much has been done in recent years to alleviate this, such as by using air or hydraulically operated chucks, on the horizontal type of lathe one vital factor seems to have been overlooked, namely, the height from floor to levers and lathe slides. On investigating 10 machines, centre lathes, and turrets of English and American makes, there was a variation of 9 in., from 27 in. to 36 in. from the floor to machine slides, and the English types were the worst offenders. It is always possible to pick out the lathe operators in a workshop because crouching over the machine invariably gives them, in time, the " turner's stoop." It almost seems as though designers are still influenced by the traditional saying which refers to work as " getting down to it." On the vertical machine, however, the workman stands erect throughout the machining operations.

Swarf Disposal. It is only recently that this problem has been tackled on the lathe, but on the vertical type the law of gravity and centrifugal force makes this problem non-existent so far as stopping the machine for clearing away the swarf is concerned.

Rigidity. The design of the machine with no overhang and with work lying down gives a rigidity lacking on the lathe.

Output. By reason of the more powerful drive and having two tools in operation, heavier cuts can be taken on work and greater output can be achieved. Broad forming tools can be used, and rough feeds with flat tools can be used for finishing cast iron. At one firm 10% less time is given on vertical turret lathes than on the horizontal type.

Maintained Accuracy. Whereas on the lathe, weight of chuck and work and stresses during machining must eventually cause wear in spindle bearings, throwing it out of alignment, on the vertical machine the accuracy of the machine is not impaired, as any wear only causes the table to settle lower on conical bearing and adjustment to nuts on end of spindle takes up any end play that may occur.

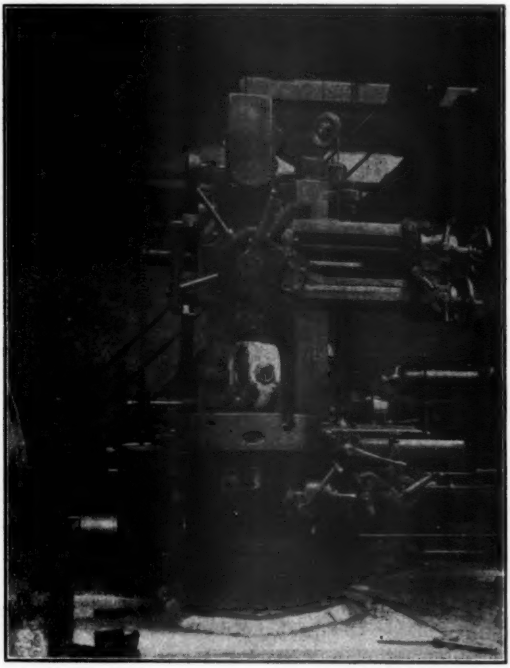

Fig. 2.

This machine (Fig. 2) is fitted with side head, and it is claimed that not only greater rigidity is obtained by having it in this position, but also control is centralised and unnecessary movement of operator eliminated. It also ensures that pressure of tools while cutting are both in the correct direction, towards the machine and not pulling away, as when the left hand tool post is mounted on the cross-

slide. It has been stated that a side head may look an attractive proposition on paper but is not always economical. I have found that on boring mills with a work capacity over 3 ft. the side head is a distinct saving, and even on a 24 in. table machine it is common practice to use both side head and vertical tool post at the same time. The boring mill, therefore, with only one tool post will be distinctly slower in output than a machine of same size fitted with side head or additional tool posts on vertical slide.

The influence of tradition is apparent even on these machines, as the direction of rotation of table is the same as the lathe, whereas it would be of greater advantage to the operator in a clockwise direction. It is all a question of which is of more importance—operating the machine's levers or gauging the work. A decided example of this is evident on certain horizontal boring machines, where on some the facing head and levers are on the left and table and work on right. This entails the operator moving levers with his left hand, allowing his right hand to perform the more delicate operation of gauging the work, which in my opinion is the correct method ; whereas on the other type of machine the position is the reverse.

Referring now to the V.T.L. in question, assuming that the table rotated in a clockwise direction, the side head would thus be on the left side of the machine, and as most of the machine's movements have quick power traverse (which should preferably be) operated by foot pedal, the use of left would not be excessive, also the weight of operator's body during pressure on foot pedal would now be on his right leg. Gauging would then be done with right hand without having to go to the other side of the machine. Other interesting features of this machine are : Entire body of machine is one casting, independent and universal three-jawed chuck, gear changing is also effected by a " pick-up " lever and lubrication is by oil pump and gravity feed.

Provision is made on the side head for screw cutting. Here then, is an output machine, and yet so deeply rooted is tradition and the horizontal complex, that its true value has not been fully appreciated. This is evident on looking round many so-called up-to-date engineering works, where the lathe still predominates. One thing is certain, that while the tool room lathe, large gun lathe and certain screw cutting lathes will necessarily remain, the ordinary lathe in the shop, despite its remarkable progress during the past twenty-five years, will surely disappear ; for the same law, " the survival of the fittest " operates here as in nature. Like the horse, the lathe in the past has served its purpose in industry, but with the march of time must make way for more efficient machines.

New Ideas Overcoming Tradition.

During a discussion on the chip problem at a lecture of the Institution of Production Engineers a few years ago, someone suggested placing a machine upside down to overcome the trouble, and a few years later a new machine was introduced designed on these lines.

Gyromatic Six-Spindle Vertical Automatics.

The outstanding feature of this machine is that the chucks are inverted, and the tools are applied to work from underneath. There are six spindles, one, of course, being a loading station. It is claimed, and reasonably so, that a bar mounted vertically has not the same tendency to " whip " as when held in the horizontal position, and in practice at high rotative speeds, providing the bar is reasonably straight, the bar runs centrally with little friction or noise, and no feed is necesary as the bar is fed against locating stops by its own weight.

Floor Space. This is stated as being one quarter of that taken by a horizontal machine of same capacity, and all danger of accidents occurring through rotating bars is removed.

Swarf Disposal. The vertical disposition of the bars has a particular advantage to drilling, as it facilitates the removal of chips from deep holes. All the elements are mounted on three round pillars, and independent tool movements are imparted to tool slides by separate easily interchangeable cams. There are six turning slides and six facing slides, and these, with the spindle speed of 2,520 r.p.m., give a high rate of production. Drilling attachments can be provided to all six spindles, and screwing attachments up to three spindles. The range of Gyromatics are available for chuck and bar work, and in general the machines are identical, except that the headstock and all the movements are the same, with the exception of the spindle at the loading station, which in the case of the chucking machine is automatically stopped and set in rotation again. On chucking machines the work is generally held by air operated chucks. It is claimed that this machine is not only suitable for cemented carbide tools but also for tools with even greater cutting capacity which sooner or later will be introduced. This machine is therefore a noteworthy example of design breaking away from tradition, particularly in the use of round pillars for the sliding members. One can trace very easily the reason of flat slides, etc., from the days when accuracy depended on the hand scraper, and grinding machines were still unthought of ; and having become firmly established, tradition did the rest.

In passing, it is worthy of note that quite recently a radial drill was introduced in Germany on which the radial arm was fitted on vee slides of square upright column, rotation being effected by bearing in base of machine. Sixty years ago a radial drill incorporating the same features was built by Dean, Smith & Grace, of Keighley.

Another interesting feature on the Gyromatic is the method of loading the bars. When the machine is in operation the chucks and tooling slides are entirely enclosed with guards fitted with windows. This point until quite recently has been overlooked by designers ; yet it is only logical to assume that as the speed of cutting increases a stage will soon be reached when guards will be absolutely essential, as it will be dangerous to be anywhere near the tool point when cutting is in progress. Visualise, for example, turning brass at a speed of 2,520 r.p.m. and it becomes apparent that some protection for the operator is necessary.

The transference of skill from the man to the machine in the past has been brought about mainly through designing to increase production, but the revolutionary increase in cutting speeds is creating another factor that will in time require even lathe operations to be automatic, because, if you have the work and tools enclosed, visibility is limited, and accuracy other than that attained automatically will be difficult.

Holbrook Auto-lathe.

Another example of design breaking away from tradition is the Holbrook Auto Lathe with a clockwise roatation of spindle, although Holroyds in 1930 were the first, it is stated, to develop a lathe on these lines. It is claimed that by this method the chip problem is overcome, as the chips move in a downward direction from work. Smooth finish is obtained, and heavier cuts can be taken than on ordinary lathes. This, it is stated, is because pressure of cut pulls the spindle down on to the bearings, and when wear does occur it will not be evident on the work. This is apparent from the well-known method of holding parting-off tools and broad tools for forming in the back tool post, on a lathe where " play " in the spindle has occurred. While this would be impossible with the tools at the front, no trouble is experienced when they are held in an inverted position at the back.

This machine, described as " Quick cut " electric and hydraulic auto turning lathe, has a speed range from 80 to 2,500 r.p.m. a noteworthy feature being the tachometer whereby the r.p.m. of spindle can be checked by giving the knurled nut a few turns, after which it may be released and is then out of action. Tachometers are as essential to the modern machine tool as the pyrometer to the hardening department. Hydraulic feed is used for front and back carriage slide, and can be set from 0 to 20 in. travel per minute, with a con-

stant return and quick traverse of 25 ft. per minute. The hydraulic pump is of the constant pressure type, working at approximately 100 lb. per square inch, with release valve.

Electric controls for headstock, hydraulic pump, and suds pump are positioned on headstocks so that each unit is controlled by start and stop push buttons. The three separate motors are concealed in the back of cabinet base. An adjustable lamp is integral with the machine, a feature sadly neglected on most machine tools. This machine is intended for work held between centres, and for work partly machined on turret lathes which must go between centres

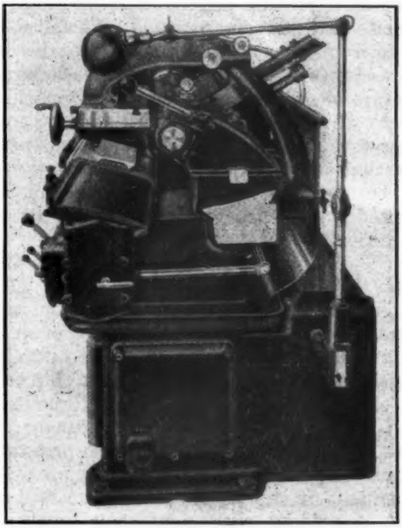

Fig. 3.

for progressive operations, this Auto Lathe, it is stated offers unique facilities. After duly considering this type of machine, the question naturally arises, if this machine has overcome the chip problem and increased production, why not make most horizontal turning machines with a clockwise rotation of spindle?

The Scrivener High Speed Multi Tool Lathe.

The outstanding fratures of this machine are first: its ability to produce work at extremely high speeds in one cut, giving a very high degree of finish. Secondly, the dispensing with gears in the

spindle drive, this being effected by vee belts direct from a 15 h.p. motor running at 2,800 r.p.m. Variation in speed is attained by changing motor pulley, provision also being made in the tension arrangement of vee belts. As an alternative, a variable speed motor can be used. The special care taken on this machine to ovecome vibration is evident in the robust design of machine bed and the mounting of the motor on a seperate bed plate inside the machine bed, with shock absorbing material placed between the feet of motor and bed plate, A spring loaded damper fitted between the bearings has the effect, it is stated, of smoothing out the peaks of periodic vibrations sometimes associated with ball and roller bearings. In the tailstock the centre is mounted at the end of a free running spindle on taper roller ball thrust and roller bearings. The tailstock barrel slides in its housing, and is spring loaded so as to exert a predetermined pressure on the centre. In the passing of the lathe from chucking and centre work semi automatic machines like these may be the intermediate stage to the more general adoption of vertical machines.

No. 12 Bydermatic Lathe.

This machine is a fine example of the application of electrical drive and control to the machine tool, and so far has not succumbed to the prevailing fashion of vee belt and tex-rope drives. After loading the chuck or placing work between centres the operator pushes the start rapid traverse button, and from this point the operation becomes automatic. The main motor is started, rapid traverse stops and the feeding stroke begins. At the end of each cutting stroke rapid traverse is engaged, the slides return and the spindle is brought rapidly to rest. This machine is all electrically controlled, four motors being employed, two ¼ h.p. motors for suds and lubricating oil, 7½ h.p. for spindle drive, and 2 h.p. motor for rapid power traverse. A noteworthy feature, apart from the push button control, is the flood chamber, illuminated with electric light, which goes out when lubrication is not functioning properly. The ammeter is also in a prominent position.

Chip Disposal. All chips flow with cutting lubricant down a chute to container at the rear of machine, and can also be used with existing systems of swarf removal. The chute in the body of machine is lipped to overhang chip conveyors, the dimensions from the lip to the floor level being 13½ in. When used with chip conveyors or arranged specially for machining cast iron a small base is used, giving a further saving in floor space. If desired, high speed drilling attachments can be fitted to this machine, so that drilling can be undertaken at a higher speed while diameters and faces of components are being machined.

Ryders No. 6 Vertical Auto.

As cutting times are reduced, loading and setting-up becomes more important than ever, and on this machine the ideal is achieved by continuous production. This six spindle machine is worthy of note as it incorporates built-in motors, consisting of stator and rotor units, actually built into the machine casting. The different movements of the machine are all controlled by motors, i.e., spindle drive, rapid traverse and indexing, and there are mechanical interlocks operating cut out switches on the panel to safeguard the machine and the operator. Flood lighting of the loading station is built into the machine. Variable speeds and feeds are possible at each station, and in cases where comparatively simple parts are to be machined it is frequently possible to duplicate tooling and half of the spindles, thereby halving the production time. The switch gear is built into the machine.

Another interesting recent example of ideas breaking away from tradition is the Bullards Rota Broach, which produces a combined milling and broaching action, making it possible to rough and finish work in one pass of tool block. The advantages claimed are: length of tool life without re-grinding; maintenance of smooth surface finish and accurate dimensions; the economical removal of a large amount of material in a short time with the least consumption of power, and without sacrificing tool life and surface finish.

Traditional Faults in Design.

It has been stated that the greatest enemy to the foundry is the designer, who will not leave beauty of form alone, and concentrate more on an even thickness of metal. But is not the foundry the greatest enemy to the machining department? The excessive machining allowances on almost all castings is still the practice hallowed by tradition, when every reason for doing so has disappeared. One reason for large allowances was to ensure that the tool got well under "the skin." With the tools then in use this was necessary, but to-day with cemented carbide tools, unaffected by sand and scale, smaller machining allowances could be used. This question of excess material on castings and forgings is to-day one of the most serious problems in the machine shop. With traditional exactitude the attacking of the time factor in machining has been successfully carried out, reducing hours to minutes, and minutes to seconds. Can it truly be said that the same energy and thought has been expended on material saving? Yet it is obvious that this is the most important problem of all, for by reducing the amount of metal to be removed, money is saved on forgings and castings, the time taken to machine is reduced, and power consumption lowered.

Beauty of form has often to be dispensed with, but neatness of design is always essential in machine tools ; yet how many machines are spoilt by the projecting of hexagon headed screws, when allen screws could be neatly tucked away in the body of the machine ? Operating handles and wheels are still made smooth and shiny, when dull serrated levers and wheels would provide a better grip to the operator.

On boring mills where the spindle is hollow for chip disposal, not only is the diameter of bore too small for adequate chip clearance, but invariably the hole tapers to small diameter half-way down the spindle, causing chips to choke up the hole. While the balance weight for the side head on some V.T.L. was neatly tucked away in the machine column, no provision is made for the possibility of the cable breaking, the only protection for the driving gears, which are immediately below, being a thin tin cover, and to prevent a recurrence of weight smashing on to gears pieces of thick wood have been used as a safeguard.

Machines made in one casting may help rigidity and design but it usually makes repairs to the machine an awkward job. It is no uncommon occurrence to have to strip a machine to replace a screw that has dropped out of the sliding key.

On hand-operated chucks, why is it necessary in obtaining an effective grip to use a pipe on end of the chuck key ? Either a finer thread should be used in the chuck screw, or a longer arm on the chuck key should be supplied.

Lubrication on many machines still leaves much to be desired. Take the case of gravity feed : on starting, the machine runs at least three minutes before oil, pumped out of oil-well to filter, is distributed to the various pipe lines to the bearings. Force feed is, of course, a solution, but an arrangement whereby the bearings are flooded before starting and relying on gravity feed when in motion would also solve the problem.

No provision is made in many cases for the handling of heavy chucks and work on lathes should no crane be available. Machines under these circumstances should have an adjustable cradle arrangement which could be placed on the saddle. The work is placed in position and the saddle moved up the chuck ; movement of a lever then lifts the job to right height and position, and chuck jaws are then tightened on to it.

Traditional methods of lighting still prevail. There is no reason why more than one lamp incorporated in the machine should not be used, such as one for illuminating the work and one for reading graduated slides, etc.

Machine Tools of the Future.

Finally, having traced the beginning of the machine tool and followed its development in one direction, having also indicated

the effects of tradition and the gradual breaking away from it, one can very broadly define the possible trend of design. Three factors will have an ever-increasing influence: flexibility in production, automatic operation, and increased output.

Flexibility in production will indicate machines with a versatility and capability of changing over quickly from one operation to another.

Automatic operations will become more widely used owing to the continued shortage of skilled labour, and enclosure of "work area" round the tool point.

Increased output will alter the design of machine beds to enable swarf and finished component to be removed on belt conveyor.

For machines used in smaller and general workshops, electric and hydraulic transmission will co-operate to give a reliable and efficient service. Flexible drives of to-day will probably be replaced by the hydraulic rotary motor.

Vertical automatics, because of their compactness and aptitude for automatic transference of work from chuck to conveyor will be used in ever-increasing numbers. Speed variation, dependent now in most cases on an elaborate and expensive gear-box, will probably be obtained more and more through the medium of hydraulics and electricity. One thing is certain: that within the next twenty-five years revolutionary changes and developments will occur as great, if not greater, than in the past. We have rid the workshop of a forest of belts; we have slowly transferred the skill of the man to the machine; but how long will it be before the machine shop resembles the proverbial Chinese pill factory, with a hundred men in the office and two men in the works? In conclusion, I wish to thank Messrs. Alfred Herbert, E. H. Jones, Ltd., and Thomas Ryder & Sons, Ltd., for the loan of slides.

Discussion, Birmingham Section.

MR. H. F. SPINKS: I have listened with great interest to all that Mr. Hewitt has said, and I should like to know something more about chip removal on the Gyromatic. It strikes me as being a very formidable obstacle. As the machine is completely enclosed, if the swarf is coming off in long curls, I think the casing would be completely filled in a few minutes. Can he give us some more information on that subject?

MR. HEWITT: In the first case, there is an arrangement on this machine for breaking chips so that they do not come off in long curls. The same principle is applied on this machine as on the Ryder's vertical machines whereby they flow away with the cutting lubricant. Whether they do so or not is a matter of conjecture. I have not actually seen one in operation, but should imagine that a machine of such great output as this would have a method of overcoming that problem.

MR. THORNELOW: The speaker said something about the vertical turret lathe having great advantages over the horizontal machine, and being more rapid in operation. Some time ago I saw a horizontal machine of the turret type which had to machine some turbine casings. In these casings it is necessary first of all to take a trial cut through the bearing caps, then remove the bearing cap and clock up to ensure that the bearings are, first of all, dead halves by measuring one of the bearing caps on a flat table and then by clocking the casing at each end to ensure that the axis through the turbine housing shall be dead centre. This would be very difficult to do on a vertical machine, because it is much easier to put a clock on a flat bed where gravity keeps it down than to hold it steady on a vertical edge, and in this particular case, although the operator was new to this job, he got the previous time of 120 hours piecework time, and time for this operation including finding of new tools, down to forty hours for one casing. After that, on the next one he got it down by 25%. Another fact is, I should imagine it is rather difficult to keep suds on a job on a vertical turret lathe, and also the danger of swarf. On a horizontal turret lathe, it is very easy to stand to one side when there is any swarf flying. There was at Olympia a very nasty accident due to flying swarf. I should imagine it is not at all easy to dodge swarf from a vertical turret lathe.

The speaker mentioned something about boring holes with a clockwise or anti-clockwise rotation of the spindle. With the

modern ball and roller bearing spindle provided the spindle bearings are good in the first place, and wear does not appear in less than five years, it is not necessary to put the parting or form tools in the rear tool post. It does not make any difference—the spindle won't lift at all. Provided the job is rigid, it won't make any difference whether the parting or form tools are in the front or rear tool posts. Then again, it is very useful on jobs which have a length scale of, say, five diameters or more, to have a three-point steady, even on a turret lathe. I should imagine it would be very difficult to arrange one on a vertical turret lathe. Another point is, if one were drilling a long hole, the vertical turret lathe has the same disadvantage as the capstan lathe, as against the true turret lathe, because of the overhang of the tool-carrying slide as well as the long drill, whereas one merely has the long drill and depends on the rigidity of the tool only, instead of the rigidity of the slide and the tool. Again, in the Gyromatic, the spindles appear to be supported round one central column, and those appear to be divided into pairs. I should imagine it is much more difficult to hold the spindle structure steady than on a horizontal machine, where one can provide several supports along the floor.

MR. HEWITT : I purposely made my paper as definite as I could in order to get some data on the comparison between these two types of machine, the vertical and horizontal types of turret lathe—and I am getting it ! I used the inverted forming tools on lathes as an example. I did not say that wear does occur on the modern lathe spindle bearing as when brass bearings were used, but we do know that if there was any chatter occurring on a modern lathe with a form tool held in the front tool post, and you placed the tool in the back tool post, the tendency would be lessened. On large boring mills, when turning vee grooves in rope pullies, the left-hand tool post is used for the forming tools and for boring, the action on the tool being the same as that of the forming tool held in the back tool post on the lathe, but whereas chatter would occur if the right-hand tool post was used, when the tool is in tension—being pulled instead of pushed—no trouble is experienced. I used that illustration, of Holroyd's Auto Lathe, to show how this pull enables heavier cuts to be taken, besides overcoming the chip problem.

By the way, it is only really in the experimental stages although Holroyd's have many in use.

As far as holding the clock arrangement on a vertical type is concerned, I do not see any difficulty, you can hold it just as well on a vertical machine. An arrangement is made to hold it, either in the side head or in the vertical tool post itself. We do not just lay it flat down on the table. The vibration of the machine itself may alter the accurate reading of that dial, but if it is clamped in

the tool post, you should get a more accurate reading.

With refence to Mr. Thornelow's remarks on suds and flying swarf, most vertical machines are fitted with guards when using suds, and the danger from swarf should be no greater than on the horizontal machine. The direction of chips can be largely determined by grinding the tool accordingly. Steadies on vertical machines are, of course, impractical, I won't say impossible, but it is common practice to hold the job in a running centre held in the vertical tool post, while the side head is rough turning the component.

Mr. Thornelow : In this particular case it is necessary to move the clock over a considerable length from either side of the lathe. One would have to have something to rest it on, therefore one would have to clamp it up to two fixtures of equal height, which would take longer.

Mr. Hewitt : By means of the rapid power traverse, the clock indicator clamped on the tool post can be quickly brought to any position, whether vertically or horizontally, so there should be no difference in time. It is obvious, however, that the vertical machine, like all others, is not suitable for all jobs, and perhaps Mr. Thornelow's job is one of them.

As for deep drilling, there is no difficulty. I should imagine the advantage lies with the horizontal type only because on the vertical type, with deep drilling there is a tendency to choke the drill, except in the case of the Gyromatic where the chips flow away. From the design of the tool slide it looks as though vibration could easily occur, but I should imagine that with tremendously high speeds, such as 2,500 revs. per minute, that will have been taken care of by the designers.

Mr. L. F. Broadbent : From the title of the paper, I expected to hear that the designer was going to be censured, but I think, after hearing the paper, that designer really has something to be proud of. It would appear from slides shown of the very ancient designs, with the modern machines shown following them, that the designer is really doing his job and getting away from tradition. Tradition is very valuable, but there is one point I would like the lecturer to mention, and that is, grinding. Everyone knows that centreless grinding is a clear-cut example of how modern machine tool design is getting away from tradition. We are doing away, of course, with centres and the necessity for centring the components, and I really think that the designer is doing his job. I am not clear whether the lecturer thinks he is or is not doing his job ?

Mr. Hewitt : I do not regard grinding as having any tradition at all—(Laughter). Compared to the machines mentioned, the grinding machine is a mere baby ! There was an advertisement in *Machinery* a few weeks ago concerning the application of the first

electric drive to a drilling machine, which showed that the engineers of that time regarded the innovation with grave doubts. I use this as an illustration to prove that the rotary hydraulic motor is in the same position to-day as the electric drive was at the time when it was first introduced, and that tradition is not always valuable.

MR. BROADBENT: The point is, did you mean to imply in your paper that the designer was not doing his job, that he was tradition bound, or that he was doing his job?

MR. HEWITT: The title of the paper is "The Influence of Tradition on Design"—not on the designer!—(Laughter).

MR. I. H. WRIGHT: When I first saw the title of this lecture, "The Influence of Tradition on Design," I thought I was going to come and hear somebody talking about the development of motor cars, or something like that. It appears that the only field in which design exists is in machine tools. Of course, I have thought so a long time, but been too modest to say it!

Mr. Hewitt, I consider, has been very polite in calling his paper "The Influence of Tradition on Design." In one sentence in the early part of his paper he told the truth a little more when he said something about the influence of the customer on design. I think that is far more important. Progress in machine design, like progress in motor cars and progress in everything, is not the result of the designer altogether, except to carry it along just so fast as the user can adopt it.

The machine tool maker who invents an absolutely new machine, and turns the machine quite the other side up from what it has been before, is going to suffer from the fact that Mr. Hewitt mentioned several times, a time lag, and if he is in a hurry to get this innovation adopted he is going to have to spend a very great deal of money in propaganding, and it is very doubtful whether he will ever see any return for that. By the time he has persuaded a few users to try his improved machine, some one else is making one just like it, but $\frac{1}{8}$ in. wider, and getting the benefit of his propaganda. So that I think Mr. Hewitt might put a little more stress on this fact, that it is only when you have persuaded the customer to have it that the actual improvement occurs.

Considering the slides that Mr. Hewitt has shown, it seems to me that when the drastic departure from boring horizontally to boring vertically has once been made in some particular field, development has really been very good. For instance, the Gyromatic is really a very drastic change. It has, however, only had a chance of acceptance at all because the vertical type of machine has been in existence for twenty or thirty years, and that, fundamentally, the alteration which Mr. Hewitt attaches great importance to has already been made, and we have been developing it in detail since then.

Mr. Hewitt also spoke about the use of ground slides. The use of ground slides is increasing very rapidly. I have been in close touch with ground slides for some considerable time, and so long as the design of the parts is such that the grinding can be done effectively, there is no doubt, in my opinion, that the ground slide is superior to the scraped slide. The ordinary commercial scraped slide has a lot of nice freckles over the surface of it, hollow places, which are not visible until the machine is worn down a bit.

Mr. Hewitt mentioned the hydraulic motor. It is over thirty years ago since hydraulic rotary motors were very thoroughly tried out, and there are certain difficulties about the use of them, one of the important ones being that unless you have an enormous volume of oil in circulation, and an efficient means of keeping it cool, you get trouble from heating the oil. Pushing oil through small ports gives rise to heat, and that has to be disposed of. The hydraulic motor we expect to give a smooth drive without vibration, but it does not do so unless the hydraulic motor runs at a good speed and is geared down to the limit. If it is doing a moderate speed, it is liable to be rather jerky, and it is possible for it to produce rather the same effect that used to be produced in old lathes in encouraging coarse chip-building, which is one of the causes of chatter if the machine will permit it.

Mr. Hewitt mentioned several times the clockwise rotation of lathes. In the old days the tool was carried on a column, rather a flimsy structure, and probably a light side, because most lathes were 12 in. centres or round about that, whereas now they are probably, say, about 7 in. height of centres, and after that the cutter was overhanging a little giving an unstable condition in those slides. Whereas, if the lathe ran the other way, pulling up at the slides, it produces a suitable condition of tension in the slides; of course the slides have to be designed for this. In fact, in those days it was quite a common thing in, say, single-pointing the bore in something fixed on the face plate, to turn the projecting boring tool wrong side up and cut along the back inside, leaving the work rotating in the same direction but cutting along the back of the hole instead of the front. It was a general practice.

In the early automatics of twenty-five years ago, it was absolutely the rule to put any form tool, or parting tool wrong side up at the back of the lathe so that it was operating upwards on the slides, and the slides were made suitable for taking an upward pull.

Mr. Hewitt also expressed a kind of regard for round slides. For precision movements, round slides are not very bad, but if you have to locate two round slides very accurately to give a sweet, accurate movement, it is quite a job, and if the span is anything at all you cannot support these round slides at any intermediate point, and they are quite out of the question.

Mr. Hewitt also spoke about the rotating broacher. That is another case where I believe that newspaper propaganda and the technical journals are trying to overcome tradition, and the tradition in this case is that a cutting edge should be presented to the work with a certain angular relation, a certain amount of top rake and included angle, which in this rotating broaching does not occur.

The rotating broach method was used for boring, to my knowledge, twenty-five years ago, and it failed because if there is any depth of cut to take off at all, the rotating broach, when it is beginning to cut, is presenting its cutting edges at awful angles, and unless the depth of cut to be removed is very small and the diameter large, the rotating broach is a contradiction of all tradition in the use of cutting tools.

There is no doubt that tradition has a very considerable influence because it is only quite seldom that an entirely new machine can be made. As a rule, new machines are bred from old machines. A machine is wanted to do some new operation, and some existing machine is taken and altered a bit, additions made and a little rearrangement, until it does the job. If any number of machines are later required for doing this operation, the tendency is naturally to make new machines embodying the practice that has been set up on this first machine, and in so far as it is made from the old machine, it is carrying on tradition. But, after all, tradition is a fairly safe guide. When a machine has a lot of innovations about it, the people who are persuaded to buy it may be persuaded that it will be economical, but the operator, who may have had a year or two on a traditional machine, comes to the new machine and does not like it, and if he does not like it, the machine is not received in a very friendly way, whereas the rather more conventional machine is quite likely to be received and to get into effective production much more quickly.

Mr. Hewitt: I expected Mr. Wright to get up and slate me because of my reference to his statement "that vertical machines with the object of space saving have made little progress," but he dealt very kindly with me and proved to me to-night that tradition has played an important part in design. When I used this title for my paper, I was rather dubious as to whether anybody would agree with me at all. It has been admitted already to-night that tradition still plays an important part.

Mr. Wright says tradition still rules in the shop, and that the buyer still exerts an influence on design. I always thought the machine tool maker had a definite say on new machine tools; they should certainly take the lead. Conservatism, however, still exists among buyers, and while it is a debatable point as to whether the efforts of progressive machine tool builders will ever be fully appreciated, it is up to their salesmen to convince buyers of the merits and capabilities of their products.

His first reference, I think, was to the rotary hydraulic motor, about it being jerky at slow speeds, and heat troubles. I won't question his statements, but I have a letter from a gentleman, Mr. Town, who gave a paper on Hydraulics which received the Waters Prize, and he praised the rotary motor highly. "It is of course expensive as it combines a pumping unit and the hydraulic motor unit, giving a combined efficiency of about 80%. On a machine tool, however, efficiency is not the main factor but work output, so that where a wide speed is required the hydraulic drive is the most suitable."

I have seen the hydraulic drive to the work feed on a Lunds' Precimax, and no jerkiness is apparent at slow speeds. I should imagine the difficulty of cooling the oil offers no unsurmountable difficulties. He also substantiated my remarks about having the tool the wrong side up. The old turners used to do it that is why I used it as an example.

He mentioned the ground slide. I was rather interested to find that accuracy had not reached perfection in the machine tool world yet. I thought all machine tool makers were working to .0001 in. I am not a machine tool builder—I use machine tools. Regarding the rotary broach, a few years ago I made a tool of the circular type, so that when the cutting edge was worn it could be turned round to present a new cutting edge, and I made my cutter with serrated edge on the top like a milling cutter, with a ball bearing underneath leaving the cutter free to rotate. I found I could run about 25% faster using this method. In operation pressure of the tool on the work, and the traverse caused the tool to rotate, giving rise to a milling and cutting action. And instead of the cutting action being at one point, it was distributed all round the diameter of the cutter, which was about 2 in.

Mr. Wright: I should like to clear my character. Mr. Hewitt says I have changed my views, and that I said vertical machine tools were not advancing.

All I said about that was that the general change to vertical boring machine tools which was prophesied ten years ago has not fully materialised. I say that the disc cutter that Mr. Hewitt has re-invented has been used for thousands of years for turning marble columns and stone blocks and that kind of thing, but with a disc of 6 in. diameter set to suit the angle of cutting and it cuts with a planing or turning effect.

Mr. E. W. Field: Might I interpolate to ask Mr. Wright if the flutes in the columns were produced by chatter in the spindles? I was unfortunately unable to hear the early part of Mr. Hewitt's lecture, but I should like to compliment him on two things, his pluck in taking the subject, and secondly, on the excellent way he has prepared and put it over. I think there is one thing we should not lose sight of before we go too far with this subject. In my opin-

ion, evolution is the mother and father of tradition, and whatever your product be, in cast iron or steel, evolution is the basis of design, so that the question is rather one of evolution than of tradition. I think the word was probably not selected with the thought it might have been.

I am not quite clear whether Mr. Hewitt claimed that the vertical machine disposed of the swarf problem, but I think he went even so far as to say that the swarf problem on the vertical machine was non-existent. Not many weeks ago I was visiting a certain shop where they ran a battery of vertical machines, in company with two directors. One of the directors drew me to one side and said, "We won't go down at the same time; he is always very happy when he walks down that line, because of the advantage that tungsten carbide gives to operators." The operators doubled the speeds of the machines. and all the swarf went over the directors; one of the machines was running wet!

Mr. Thornelow has given an instance of the time factor on a horizontal machine as compared with a vertical one. I should like to take the point one stage further and say very definitely that where a true comparison can be made of capacity between a vertical single spindle machine and a horizontal. I have yet to see the vertical machine that can hold a candle to a horizontal for production times. The vertical machine also brings to the fore the very great danger and difficulty of satisfactorily balancing it. On one well-known modern turret type, where they have adopted a spring, the difficulty is balancing it. I saw a very bad accident because one sprang back. Cables can break, and that is probably a safety margin in certain structures. The vertical machine, however, is not only difficult to balance, but it presents grave difficulties in balancing the rotating weight if the position of the turret is automatic.

Mr. Hewitt went on to foresee, within a measured number of years, the complete disappearance of the lathe. That takes me back to the statement made after the war that we should never want any turret or ordinary lathes again, and yet I think it is true to say that, as a productive machine, there are more lathes and turrets made than the whole of the other types put together.

With regard to the Gyromatic, this is an excellent step in design undoubtedly, but one of the most difficult machines in the world to set up. I understand they are raising operators in Switzerland with prehensile arms to go round the various nuts and bolts.

Mr. Hewitt also made quite a point of clockwise versus anti-clockwise rotation. This question has been brought to the fore in recent years, largely by the tungsten era and the rapid production of swarf. It may interest him to know that my own company have produced many thousands of lathes since 1914 where the headstock

is just as powerful on the reverse stations as on the forward strokes. One reason why clockwise rotation of machines has not been more largely adopted is because the machine is not doing anything on the reverse, we simply use the reverse action to obtain cutting under tension when this is necessary .

I was pleased to hear him stress the necessity for the tachometer built into the machine. Most of you who have heard one or two remarks of mine will know that I have fought for that, praised its efficiency and utility, on more than one occasion. Mr. Hewitt also mentioned the apparent lack of individual lighting. That has been true up to a point for many years, but there is nothing difficult about it, and on almost any machine you can have a light fitted on, assuming your current is suitable. It is only a matter of a few shillings. Mr Hewitt further went on to criticise the chuck where the operator has to pick up a length of tube to tighten it. That is a safety first precaution, and simply means that he is not satisfied with the power he can put into the ordinary key. There are some modern chucks with a very much finer scale than the old type, where no tube is neccessary, and the man can grip a piece of work satisfactorily, so that cuts up to 60/70 h.p. can be pushed against the job, by an ordinary chuck key.

MR. HEWITT: With regard to production times, I noticed in *Machinery* a few months back there was an article dealing with machining times on Stub axles. There were in this case two Drummond lathes on standard commercial vehicle axles. They installed a Rydermatic for roughing and finishing both operations. It takes eighteen minutes to rough, the finishing time was not given, but stress was laid on the fact that these two machines were done away with. Where gear blanks were to be turned, they were turned on Rydermatics ; for large quantities they used vertical autos and automatics; small quantities were done on vertical turret lathes. No mention was made of turret lathes of horizontal type. I have seen a machine, a vertical turret lathe, 36 in. table diameter, where a cast iron bevel, 4 in. face width and about 30 in. diameter, has been completely machined in an hour. I do not think there is a lathe in the world can compete with that time ! I have purposely left times out, hoping that somebody would bring the matter up. On routine work and repetition work I think vertical machines are at least equal, and I want to get a few to-night to say where lies the difference. I know one firm who give 10% less time on the vertical machine than on the horizontal type. Evidently they must think the vertical type is superior ?

MR. FIELD: With regard to the question of stub axles, might I remind you of the inability of the special type of machine to finish the stub axles because the axle wants screwing. With regard

to the question of times. I hoped that I had made it clear in the first case. My main argument was with what we call the turret type of machine rather than the Rydermatic. The Rydermatic is one of the biggest steps forward from the turning point of view I have seen, but I would say that the machine offers a disability on blind hole boring ; for external work it is an excellent machine, but like most vertical machines, troublesome when you have any internal work to do.

MR. HEWITT : When Mr. Field speaks of blind hole boring, does he mean a hole which goes very deep ? The drilling attachment which can be supplied to these vertical machines can be used for boring blind holes and is worked from underneath, therefore I should think the trouble as reagrds blind hole turning can be overcome. On the Bullard machine they use this method : While they are turning the outside diameter and face, they have a drill coming through the hole and reaming. Regarding the screwing of the stub axle, if this is done with single-pointed tool and not a die head, it naturally could not be finished, but this would also apply to the horizontal turret lathe.

MR. FIELD : I do not think you are quite clear about what I meant. You said the drill comes up from underneath. That pre-supposes that the designer has conveniently placed the blind hole on the under side. Suppose the bore is definitely on the side that he is facing, your problem is very difficult.

MR. HARRISON : It has been very interesting to hear this lecture to-night and has taken me back a number of years. Regarding turret lathes in comparison with Bullards the latter were used over twenty-five years ago in the machining of tram-wheels. The first operation was performed on one of these, the wheel being held inside the rim by a three jawed chuck, the rim was turned on the dia top face and face of centre boss. The second operation, wheel was turned over and put on another machine in a similar chuck but held on the periphery when bore was finished, boss face and face of rim. Above operations were very quick and much easier to load than on a turret lathe. Regarding tradition of course like anything else we have good and bad and I think that is what we have realised to-night. No doubt the designer of the motor car to-day depends quite a lot on what tradition has been in the past. You can take jigs and fixtures for instance. After receiving your layout from the production department the practical man would look at this and probably make suggestions saying this operation won't be right; it is our usual practice to do so and so. This is because of certain tradition, having done this for many years knowing it to be the best method.

MR. HEWITT : Your last point made it clear that tradition has its good as well as its bad points. Of all the things I pointed out in

my lecture, some were good and some bad. Referring to these wheels, it is rather an unusual procedure to face a wheel up and bore it and then take it off the machine. Accepted practice, or tradition, is to machine the diameter and bore at the same time, and then turn over to finish the other side to finish bore first and then remove wheels to another machine. Unless you have some very accurate methods of locating and holding it you cannot guarantee the bore being concentric with the outside diameter. Reverting to Mr. Field's remark that he thought evolution should have been the word used, not tradition, to have called the paper "The Influence of Evolution on Design" would not have been satisfactory, for the whole argument of the paper has been to show the delay or time lag in the evolving of design from tradition.

Mr. Harrison : Regarding the Gyromatic I can quite understand that on bar work it would be useful but you also claim you can do chucking jobs on it. Would not this be difficult to handle the work putting it into the chuck. We go from the lathe to the Bullard because of the easier handling when loading but it would be much more difficult on the Gyromatic.

Mr. Hewitt : For full automatic working on the chucking machine, a magazine feed is required. Alternatively, it may be employed for semi-automatic operation. In the latter case, the work is placed in a suitable locating member on the top of the sliding tool barrrel at the loading station. When the machined part has been released, the sliding barrel is raised by means of footpedal or hand lever to bring the new piece into position between the chuck jaws which then close automatically. This may be done with the chuck spindle either stationary or rotating. In the latter case it is possible to arrange for the synchronization of parts having projecting portions that might otherwise foul an adjacent spindle.

Mr. Bowen : Several times this evening the Gyromatic has been mentioned, and perhaps I can clear up one or two points that have been discussed from time to time. In the first case, the Gyromatic was designed by a man who had been hampered by tradition for many years. He worked for a very well-known manufacturer of four and six spindle automatics, and for many years he had the idea of getting right away from normal practice and designing a vertical machine. In doing so he had to depart from what he might have done, that is taking hold of a standard four spindle machine and sticking it up on end. I have made a note of one or two points which may interest the members present. Normally on the horizontal type of machine the feed of the tool slide is controlled by the slowest cutting tool, although it may be altered slightly, whereas Schearer has made six rising and falling tool slides, several of which can be live. He can have two drilling, or two tapping, and two reaming. By building this machine in the way he has done on

three columns, without going into details, he has made it so that it is remarkably free from vibration, and I have seen his machine running side by side with modern six spindle automatics and the results are very favourable.

Of course, a main idea is saving floor space. I know that many people paint a picture of an operator climbing up a steel ladder, but that can be quite easily overcome, and a battery of these machines properly laid out with a long gangway alongside covers less ground than an arrangement of conventional four and six spindle automatic machines. Going up a ladder might appear dangerous, but I do not know of any reference to an accident, a steel ladder is shown, but definitely better arrangements can be made in that direction. We do not appear to have a slide available showing the machine in its normal running position, but it is totally enclosed and electric lights are provided inside so that you can see everything that is being dealt with in the event of any breakage. There are, furthermore, very good safety features incorporated to operate if any jam occurs. Another feature is the indexing. In normal machines, the indexing is taken on a ring which is nearly always less in diameter than the pitch circle of the spindle involved. The designer in this case has gone right away from convention, and his indexing circle is about twice the pitch circle of the spindle itself.

With regard to chip clearance, which the lecturer mentioned, there is a device on the machine whereby the chips are broken up to fall by gravity in the large space provided. There is a chip well and below that there is a lip which may be arranged to fit into the standard swarf conveyor chute or a similar arrangement. Comparing the machines again there is a considerably greater capacity as regards length of turning, etc., and there are also six turning and facing slides at the sides in addition to the rising and falling spindles which have tool-boxes on them. The cross-slides have tool slides which come in and traverse, either upwards or downwards, and come out again.

Another feature is the cams. Whereas on four or six spindle machine there is no suitable means of alteration to cams, with this machines the cams are standard and alterations with regard to length or feed are simply made by adjustment of screwed sleeves. One point Mr. Field mentioned was that of the operators with prehensile arms. This machine is not difficult to set up as suggested, but answering Mr. Field's remarks in the spirit they were offered, we would say that it is made in Switzerland, and as they are very close to certain countries where dictators rule and where all things are possible, no doubt such operators can in time be produced and reared to overcome even this difficulty.

Mr. Edwards (Section President): One remark of the last speaker on the question of loading facilities for machine tools reminds me that one company I have some connection with make a feature of this on some of the very heavy machines, and have hydraulic lifting tackle incorporated for lifting work between centres. The particular case I have in mind is the grinding of railway axles. These come along still assembled and on their own gauge of truck to a position between centres, and the complete axle with wheels is lifted up to centre hieght hydraulically. As soon as the centres close in, the hydraulic rams fall away. It is applied in many ways, but that is one example that occurs to me. I should like to associate myself with Mr. Field in saying how very much I admire Mr. Hewitt for tackling this subject, and for the manner in which he has prepared his paper. The discussion that has been called forth by this will, I am sure, to some extent repay him for the trouble he has taken.

Mr. R. H. Youngash: I think on this occasion it behoves me to be rather careful in any remarks I may make, because Mr. Hewitt has rather a keen power of repartee, and so I am going to say at the outset that I agree with everything he says.—(Laughter). I was particularly interested in the very early examples of machine tools, and I was wishing that he had, amongst other slides, one showing that wall type of vertical boring machine which, I believe, is still in existence at Messrs. Avery. It is a most interesting machine and an early example of the boring mill.

I can remember in my own personal knowledge, seeing at the works of Messrs. Heenan & Froude, Birmingham, somewhere round about 1896, a very large boring mill which was used in those days for colliery winding drums. It was placed in a pit, with an engine at the side, and had a table perhaps 25 ft. in diameter, and I remember seeing on one a large drum being turned and the operator had a chair on the table that went round with the work; he sat on the chair with his legs crossed and his pipe going very nicely, a newspaper in his hands.

I do not know how that would fit in with modern conditions. it would probably not be permitted to-day, or one might find perhaps six lathes on the table and he would be doing something on each of them!

I am not quite sure—though I do not, of course, disagree with Mr. Hewitt—that we have not got somewhat mixed tonight between the question of principles and tradition, and evolution has also been mentioned. It is traditional that we have watches, but the method of making watches is usually one of custom. I have recently seen a watch some 200 years old which had a little musical box inside which played a tune. Another one had a bell which rang at the hour.

The traditional part, that is the wheels and hands that told the time, were exactly the same, but the details were different.

So, I think it is with lathes. In fact, the whole subject, to my way of thinking, is rather a matter of convenience and of the demands and requirements of modern conditions. The improvements which we bring about are purely the result of taking a fresh view on some subject. For instance, one cannot imagine a vertical lathe turning propeller shafts for ships. We have at our works a very large chimney some 200 ft. high. I have often wondered whether some use could be made of it. We might put a centre at one end and a headstock at the other and use it as a lathe, or perhaps convert it into a loading station for gyromatics, but in that I do not think we have a tradition.

I have very great pleasure in proposing that a hearty vote of thanks be accorded to him for his interesting and instructive paper this evening.

Mr. Edwards: Mr. Youngash referred to the old wall-type boring or drilling machine at Messrs. Avery's.

I believe that this is no longer in commission, due to rather unfortunate circumstances. The old gentleman who used to work the machine (he worked on it for sixty years, and I believe his father before him) met with an accident, and it was decided not to continue its use. As an example of tradition I would mention that two or three years before he actually ceased work, he was transferred from this wall-type machine to a modern Asquith radial. The old chap almost wilted away, and, with tears in his eyes, asked the manager of the department if he could be put back on his old machine, otherwise he was quite sure he would not live, and he was actually transferred back to it, although this was not really an economical proposition.

Discussion, Yorkshire Section.

Mr. H. C. Town: You will agree that Mr. Hewitt has given us a most interesting paper. There is no doubt that the machine tool, like every other machine, has suffered from the effects of tradition. We progress but slowly, and with most inventions some salient features of previous devices are generally maintained. The early motor cars, for example, were built to conform in appearance to the horse-drawn vehicles of the period, and even to-day the engine in lieu of the horse is placed at the front end of the car whilst logically it should be as near to the driving wheels as possible.

Early machines were built to conform to the architecture and furniture of the period, the ornamentation on the castings being most pronounced. True it is, of course, that in the early days news of new developments travelled but slowly, and it was largely a case of the closed shop and the buyer dare not experiment very far. To-day we have the technical press, e.g., *Machinery*, and there is a great deal of research work carried out. Although hampered by tradition, the trend of machine tool design has always been a progressive one, and not a pendulum fashion in like manner to that of ladies' dresses, which one day expose the transmission details and in the next completely enclose the mechanism.

The most important point Mr. Hewitt has raised refers to the vertical machine tool as against the horizontal type. Although the first boring and turning mill was of British design, built in Manchester by Bodmer in 1838, it was sixty years later before its use became general and even now it has not quite ousted that most monstrous of all machine tools, the large face lathe. I think we shall agree that Mr. Hewitt has presented his points in excellent fashion and it should be a source of satisfaction that to-day development is taking place at a rate as never before in the history of engineering. Although we are still fettered to some extent by tradition, one effect of Mr. Hewitt's paper should be to break down the last barriers and leave a clear course for free and untrammelled progress.

Mr. J. D. Scaife: We have to thank Mr. Hewitt for an interesting paper, and I for one have been enlightened to a large extent by some of the historical details Mr. Hewitt has shown on the screen. However, he has propounded many questions and opened up numerous issues—I should like to have plenty of time to deal with them—in fact, it is a long time since I heard a paper on which I should like to contest so many points.

In the first place, I rather gather from Mr. Hewitt's paper that he finds fault with the habit of following tradition in design. I

do not think anyone could charge me with being a " stick-in-the-mud " in the way of machine tool design; at the same time I should like to join issue with Mr. Hewitt when he maintains that working to habit is a bad thing. I would say that it is a good thing to hold on to the things that you have found to be good in substance and eliminate their weaknesses. It is a scientific fact that to move forward you alter only one factor at a time, and I maintain that that is true progress. If Mr. Hewitt also maintains that some of these habits have lingered a long time I would also contest that point. These improvements in design have to be paid for, and I think you will find that in every case there has been some reason for holding on to them. My own experience goes back to the early days of one of those historical slides shown on the screen. A man has a hand tool under his arm and well I remember the use of those tools. In a few instances they have saved a dentist a fine piece of work, and I have known other men lose a few teeth in the process. Those machines ought to be in the museum, as Mr. Hewitt says. There is no economic use for them any more. At the same time I remember my grandfather once bought a lathe; the specification was for a 10 in. lathe to turn 6 ft. long and he paid £50 for it. It was a new lathe bought in Keighley. You would have to pay to-day for a decent lathe of that specification in Keighley nearly ten times as much. Now if a modern equivalent of such a lathe had been available in my grandfather's time when I was a boy in the shop, what use would he have been able to put it to? There would have been no economic reason for the tool; there could never have been a use for a machine like that at a profit in that period.

One other reason perhaps which has held back a little of the progress which Mr. Hewitt would have liked to have seen, brings us back to the economics of the job. Wages in this country—and at the same time a comparatively high degree of skill—had the tendency to keep machine tools simple, whereas in other countries, where they have not been blessed with a high average degree of skill, they had to go in for automatic machines. This factor has had its effect.

Mr. Hewitt mentioned the flange type motor. I do not think there was a long lag between that type of motor and its application on machine tools. I think that as fast as the electric motor people have developed their part of the job the machine tool maker has followed suit. For example, the rotor and stator unit type, the bare shell of the rotor and the bare shell of the stator, have been introduced into machine tools to make a compact unit. It is not many years since these were developed but they are now being used freely.

Now we come to the hydraulic principle. I do not think the machine tool trade has been slow in availing itself of the science

of hydraulics. I am rather inclined to think that in many respects the machine tool trade has jumped on to that rather quickly. For instance, Mr. Hewitt's statement that the application of hydraulic motors to lathe headstocks would be general practice in a few years' time—I hate to object, but it won't. Academically considered the principles are better, but again the economic side comes into it. Machines made with certain features have to pay for themselves. If the cost of the machine is not paid in terms of its increased efficiency, an academic idea, no matter how good, is not going to help. The cost of, say, a 25 h.p. hydraulic motor with a variable delivery hydraulic pump to operate it would be somewhere in the region, to-day, of £150-£200, which is not competitive.

You take a gear-box with ground gears with, say, a number of steps and a variable speed electric motor with just a sufficient variation in speed to give you an infinitely variable speed, and this will accomplish all that the hydraulic motor does at less than half the cost, and although the efficiency of the motor drops it doesn't drop so much as to matter within the slight changes of speed required.

Then, again, as to hydraulic applications to lathes, I am not one who is quite sold on the idea of that. I maintain that a lathe can be better operated by gears, screws, etc., in the conventional fashion, because with the hydraulic mechanisms, in spite of the fact that scientists claim that oil is inelastic, you have to contain the oil in pipes and metal which expands, and I have yet to see a lathe hydraulically operated that will give a constant feed through the whole range of its travel if there is any variation in the depth of cut. No, it cannot be done. With an ordinary lathe after so many revolutions you will get a certain output at the end of the day. In hydraulic mechanisms, especially using high-pressure oil squirting through fine holes or slots with variable viscosity throughout the day, you are not going to get any consistency in your results. That is the present position regarding hydraulic feed to lathes.

Mr. Hewitt seems to be obsessed with the idea that vertical machines are better than horizontal. The machine tool world avoids as far as possible issuing a general statement. I am acquainted with the "Bullard" type machine and the vertical turret. It has its limitations. For instance, compare a vertical with a "Herbert" No 20 for a cylinder liners 24 in. in diameter and 30 in. long. That is a typical job on a turret lathe, but with a vertical machine the man would have to walk up six to eight steps to operate it.

Mr. Hewitt objects to the horizontal face plate on account of the overhanging bearings and things of that sort, an objection which does not exist at the present time with the application of ball and roller bearings. You can eliminate wear almost absolutely

by this means. Some of the turret lathes equipped with ball and roller bearings which are used by Alfred Herberts were introduced about twelve years ago. I inquired a year or so ago about them and some of the original bearings were still in use without any perceptible wear, in spite of the overhang which Mr. Hewitt speaks of.

Mr. Hewitt said that roller bearings had been a long time in making their way into machine tool work. That is not quite right because it is only in recent years that ball bearings have been made with sufficient accuracy for this type of application. Being in the trade myself I can trace within ten/twelve years the making of ball and roller bearings sufficiently accurate for machine tools and when I was in the States not more than six/seven years years ago, I think, was the time when one important firm of machine tool makers making internal grinding machines had not yet succeeded in making suitable ball bearing spindles. We over here were using them with every success at that time, whereas in the States at that time such bearings were not obtainable. I think it can be seen that by a study of machine tool making there has been a "cause and effect" all the way through. The economic viewpoint is the safety viewpoint. You can only aim at one feature at a time, it being so unsafe to change so many things on a machine at once. These more highly developed machine tools must be paid for by increased efficiency and that increased efficiency could only be obtained as the quantities available increased.

At times I have criticised the British machine tool industry and I think with reason. We now have a protected market which will help us. This market is still, however, far less extensive than that of the U.S.A. Improvement since protection came in has, however, been rapid. I think it will increase in pace as time goes on.

Mr. Hewitt: When I started this paper I prefaced it with a few words. These were a matter of opinion and not of fact; we are entitled to our own opinion. Mr. Scaife has given us some excellent opinions. I wanted to get some data and I have been getting it—so far. Mr. Scaife thinks that tradition is good. I say it is both good and bad. It is good so long as it does not obstruct progress. I tried to show some aspects of this. I still maintain that the ordinary centre lathe and chucking lathe are not equal to nor as efficient as other types of machine tools available to-day. I maintain this: that a vertical turret lathe is the equal, if not the superior, of a horizontal turret lathe. I must not in any case try to argue on hydraulics. Time, if nothing else, will bring the price of the hydraulic motor down, increase its efficiency and make it more suitable and better altogether. With regard to the machining of a liner on a vertical machine, this would not be impossible but

perhaps impracticable. It is interesting to note that the first liner bored from Watt's steam engine were only successfully machined in the vertical position. I was very interested to know that there is very little wear occurs on ball bearings to-day.

Mr. A. Sykes: We are deeply indebted to Mr. Hewitt for the very interesting way he has put his facts before us. He has also ably traced the history of machine tools and at the same time showed us how we might avoid mistakes and learn from other mistakes. I must, however, run with Mr. Scaife—tradition is not necessarily an evil. There are many good points to be said for it. For example, take the position of the skilled mechanic and the apprentice representing tradition which has been handed down. Where would the apprentice stand were not the skilled mechanic to hand it down to him? The apprentice would experiment himself, make repeated mistakes, and would take twice as long to acquire the craft, and he would waste twice as much material. The same thing applies to our designs. I feel that a good design which has stood the test of time and has been handed down from one generation to another has a great deal to recommend it. We can easily waste a lot of time going out on a new line. Perhaps we are liable to overlook the fact that many others have set out on similar lines, gone through the same processes, made the same mistakes, and have come back to the original. Therefore the fact of adhering to tradition is not necessarily an evil. At the same time we ought to examine these traditions in close detail and see whether they are not bound by some circumstance which is now obsolete. I think that was the line Mr. Hewitt indicated. Although he has dealt very largely on the evils of tradition I believe he has at the back of his mind many good points in its favour.

Mr. Hewitt: I do believe that tradition is both good and bad; if I have stressed the bad side more it is to provoke an argument. I wanted somebody to criticise rather than praise. There is just that question of following tradition too rigidly. Design must, of course, go through a process of evolution, but if we follow that too far we shall get statements like I got at Birmingham. For example, the buyer should not, but often does, determine the design of the machine. This certain speaker said that we cannot design first and then sell the product. I disagree—history shows us otherwise. Ford, Watt, and others, they didn't wait till somebody wanted a motor car or a steam-engine—they first made the product and then created a demand.

Capt. L. J. Sarjeant: I world like to congratulate the author of the paper to-night. Not knowing much about machine tools I was very impressed with the vertical machine, especially as the question of floor space is obsessing me at the present time. I was much interested in Mr. Scaife's criticism. I have only a very super-

ficial knowledge of this subject, but one of the things that does strike me is the progress that has been made has been accelerated in the last few years because of the general interchange of ideas now common. The cost of these machines would not have been justified years ago as quantity production as we know it to-day did not exist. Machines were then used for a number of different kinds of manufacture—they were general utility machines. This development of quantity or mass production has increased the rate of progress by making these special purpose machines economically possible. One other point the lecturer made which concerned machining allowances on casting. This is an old one and one we have all been up against. One of my jobs at one time was dealing with a foundry required to produce very light castings. Breaking with the old idea of paying so much per cwt., I substituted a price per piece. This gave the foundry manager the urge to supply as little metal as would do the job and the weights, definitely came down and excessive machining was avoided. With a price per cwt. there is always the tendency to err on the heavy side. I think these are ideas relatively new in foundry production.

MR. J. FRANCE : There are one or two matters which have arisen out of Mr. Hewitt's lecture, for example, vertical versus horizontal machines. In my opinion it is a matter of convenience. It is not a question altogether of one being fundamentally right and the other fundamentally wrong. Some jobs are easier to load and operate when vertical than when horizontal, and vice versa. With regard to the direction of rotation. Alteration of this would mean the scrapping of our drills, screwing dies, and so forth. I cannot see anything fundamentally right in going in a clockwise direction as against going in a contra direction. The tradition of the clock is slightly prior to that of the machine tool. With regard to ball and roller bearings. It is said that all machine tools should be fitted with these, and yet very recently, say two or three years ago, one maker for a particular job left ball and roller bearings severely alone. After all there are certain fundamental errors in ball and roller bearings in that, taking the ball first, our load is carried on a point. Theoretically there is an infinite stress upon that point and the point depresses the surface it is in contact with. We therefore get clearance at some other place. That means to say we have clearance coming in which takes away the accuracy. With a plain spindle in a plain hole thoroughly lubricated under pressure you get much better results for applications requiring extreme accuracy. In a discussion of this kind it is very easy to look back and criticise. The same will be said about us fifty years hence ! The problem of how to remove metal from parts has occupied us all the evening. Well after all is that not fundamentally wrong ? Why put material there to have to remove it ? Won't the tendency be, as

the years pass on, for the metal cutting machine tool to become obsolete since metal will not be put there to be removed.

MR. HEWITT: I am glad you have raised this point of convenience on machines because all machines have their limits. Mr. Field of Birmingham described a job which could not be done on a vertical machine and I had to mention a job which could not be done on a horizontal machine. There are jobs suitable for each class of machine. I have been trying to maintain that the vertical machine has not received the attention that it deserves in the past and that such attention is merited. Mr. Scaife might have something to say about roller bearings not being accurate. With regard to metal removing machinery becoming obsolete, I read an article, I believe, in *Machinery* a few years ago about a man who fell asleep in the office—an engineering office—and dreamt they had no machine tools. Instead they poured some powder in a container, applied tremendous pressure and produced an article the absolute finished size out of the powder. Mr. France too may have had a dream!

MR. J. D. SCAIFE: Mr. France mentioned ball bearings under load. They are usually under heavy load. With roller bearings there is less deflection. There is a small amount of deflection with roller bearings but this is usually overcome by pre-loading. I would also like to say that ball bearings can be made at the present time with a resulting accuracy equivalent to the best fitted plain bearing. I should also like to say that the modern high-speed lathe for carbide tools would not be possible with a plain bearing to-day no matter how closely you have the fit. There is a certain amount of slack due to the oil film, which causes a certain amount of chatter and a vibration which is destructive to the very delicate edge of a carbide tool. Only an anti-friction bearing tightly fitted will overcome that and allow the high speed which is called for.

COL. BRAY: Mr. Hewitt mentioned the getting up of lathe beds. It is still quite a common practice to get a lathe up by hand whereas modern grinding is available to do the job much more accurately. Mr. Nurrish will doubtless confirm my statement when I say that we went together to a very famous lathe manufacturer at Olympia and that he or his son told us that that method (the hand method) was still used by themselves, a huge quantity being involved, and they had only a very limited number of their men whom they could trust to get up their super accurate tool lathes. What has happened to modern grinding?

MR. HEWITT: A gentleman at Birmingham tried to prove that the grinding of slides was the best way possible. He described in detail how by using a hand scraper hills and dales were made. I once read an article in *Machinery* about a famous machine tool builder in Switzerland who said: "Over my dead body will

you grind slides." In America it is maintained that they cannot get a surface absolutely plain by grinding, This is perhaps a good example of tradition; most definitely there are two schools of thought. I understand Alfred Herberts grind all their slides—I believe they have done so since 1923 but I am not certain. Perhaps some other gentleman might enlarge on this.

Mr. R. J. Mitchell: Regarding ground versus hand-scraped beds for lathe and machine tool slide-ways in general, I should expect that the hand-scraped job would have some advantages in the majority of cases. The minute hills and dales produced by the scraper serve to contain small but invaluable quantities of oil which will operate somewhat on the lines of a "Michell" bearing, due to their wedge shape. May it not be possible to have slide-ways too smooth? For example, one knows how severely two lapped surfaces will abrade each other under load. One can imagine that with enormous care and very expensive plant it may be possible to grind machine-tool slides, but to ensure a high degree of accuracy the job will entail unlimited care, very great special knowledge of grinding wheel technique, and will cost far more than hand scraping for some considerable time to come.

Mr. France: I would just like to defend myself with regard to powder and the dream. I have had some little experience with the powder idea, in fact not in fancy. Mr. Nurrish knows something about that too. On our metals of lower melting point we are nowadays quite familiar with die castings. We can attain a high degree of accuracy so that no machining is necessary. Why don't we die-cast our bigger cast-iron castings? It is because at the moment we do not know how, we have not found out yet. Again, take forgings, Levers in the past were always machined on the bosses. My first job was on a milling machine milling the bosses of bell-crank levers. Nowadays such forgings are "coined," that is, pressed between two flat surfaces to the thickness required—quite good enough for the job, and no machining takes place at all other than the drilling of the hole. Developing the idea further, perhaps the time is not far distant when instead of turning metal from shafts we shall roll them. Something similar has taken place, i.e., rolling the finish in bars. I hope I have made the points clear because the "powder in a mould" idea is not quite so silly as it looks.

Mr. Hewitt: I suggest you give a lecture continuing where I left off. I think you could very well give a paper and carry on indicating the possible trend of workshop practice in the distant future. I think Mr. France's ideas are very correct.

Mr. Smith: I would like to thank the speaker for his excellent address. I would like to propose you ask for Mr. Scaife's opinion

as an authority on grinding slides. Perhaps he would give us the benefit of his knowledge.

MR. J. D. SCAIFE: Honestly, I did not want to get up again. I have spent a lot of time on the grinding of slide-ways. I am absolutely in favour of grinding slide-ways although it is a far more difficult job than scraping. If anybody introduces a grinding machine to save money in the preparation of slide-ways he will be disappointed. It is an exceedingly difficult matter, one of the difficulties being the heating of the slide-way. I have seen a lathe bed with one heavy cut which had to stand for six hours to cool down and the bed was buckled up seven thousandths.

I was acquainted at one time with a test that was made by one of the machine tool makers with three slides—one was a hand-scraped slide, the second was a slide ground with a periphery wheel (a formed wheel with a diamond), and the third was ground with a cup-wheel to give a cross ground finish. In the subsequent test, with a specified load with the same king of lubrication, the hand-scraped slide failed long before the others. The slide-way which answered best of all was the one ground on a cup wheel. Various reasons account for this. The periphery wheel is a difficult matter to grind flat on the face and to the correct angles—cup wheels and spindle must be all so well balanced that you do not show a wave. It is an exceedingly difficult matter to get that slide-way so that if two slides are rubbed together you do not see a wave due to the slide being out of parallel with the wheel. You do not get that with a cup wheel, there is only one point will grind a flat job if the spindle is set square. When it comes to the actual grinding of slide-ways it is a difficult matter. One of the reasons against its adoption is the very great expense of a suitable grinding machine. It has to be well cared for at a very high cost. A machine for grinding a slide-way, say 8 ft. long, would cost somewhere in the region of £3,000. You cannot very well save any money by it. Another advantage in the cup-wheel method is that you can grind underneath the angles without altering the position of the bed, which is a very important matter. You grind all the surfaces without moving the bed. With the periphery grinding method you can only grind the tops, you cannot grind underneath anyhow. It is usual to keep dead surfaces dead parallel. I am absolutely in favour of grinding, but we do not grind our slide-ways because of the very high cost. In the case of slides up to 30/40 ft. long, the cost of a machine to do these would be out of all reason.

MR. H. C. NEWALL: Why is it that on a tool-room lathe the traverse handle is usually on the left-hand side and on the production lathe on the right-hand side? It is probably due to some excellent reason connected with tradition. The common-sense point of view, however, would appear to be— if it is better on the right,

why not on all lathes, but why one on one side and one on the other? If a tool-room man is used to left-hand control surely he is going to be at a disadvantage with right-hand control. Which is the better? Mr. Hewitt made a point that the buyer is the person who determines the type and the particular design of the tool. It seems to me that the buyer could very well, through the foreman, get the opinions of the craftsmen—they are the people who have to make the profit. The opinions of craftsmen are not taken sufficiently into account. They could tell us quite a lot. In conclusion I would like to propose a very hearty vote of thanks to Mr. Hewitt for a most excellent paper.

Mr. R. J. Mitchell seconded the proposal which on being put to the meeting by the President was carried with acclamation.